2016

Argumentation in Science Class: Its Planning, Practice, and Effect on Student Motivation

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This is to certify that the doctoral dissertation by

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Abstract

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Dissertation Submitted in Partial Fulfillment

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Doctor of Philosophy

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Abstract

Studies have shown an association between argumentative discourse in science class, better understanding of science concepts, and improved academic performance. However, there is lack of research on how argumentation can increase student motivation. This mixed methods concurrent nested study uses Bandura's construct of motivation and concepts of argumentation and formative feedback to understand how teachers orchestrate argumentation in science class and how it affects motivation. Qualitative data was collected through interviews of 4 grade-9 science teachers and through observing teacher-directed classroom discourse. Classroom observations allowed the researcher to record the rhythm of discourse by characterizing teacher and student speech as teacher presentation (TP), teacher guided authoritative discussion (AD), teacher guided dialogic discussion (DD), and student initiation (SI). The Student Motivation Towards Science Learning survey was administered to 67 students before and after a class in which argumentation was used. Analysis of interviews showed teachers collaborated to plan argumentation. Analysis of discourse identified the characteristics of argumentation and provided evidence of students' engagement in argumentation in a range of contexts. Student motivation scores were tested using Wilcoxon signed rank tests and Mann-Whitney U-tests, which showed no significant change. However, one construct of motivation—active learning strategy—significantly increased. Quantitative findings also indicate that teachers' use of multiple methods in teaching science can affect various constructs of students' motivation. This study promotes social change by providing teachers with insight about how to engage all students in argumentation.

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Dedication

I would like to dedicate this study to my family whose support and patience contributed towards my perseverance to complete the study.

My mother, Mrs. Shakuntala Nanda, taught me the value of grit and deep learning.

My daughter, Aradhna Taneja, stood by me as I worked through formatting issues and reminded me that I can overcome all hurdles one step at a time.

My son, Abhay Taneja's comment, "Mom, you can do it" lifted me up on the days when I was ready to quit. He encouraged me to take deep breadths and meditate when the going was tough.

My siblings Tarun Nanda and Dr. Shachi Dewan, whose constant queries of the progress I made kept me on track.

With the encouragement and belief my family had in me, I completed this journey.

Acknowledgements

I would like to thank Dr. Andrew Thomas, the chairperson of my dissertation committee for his valuable insights throughout the period of the study. The questions he raised helped me critique and improve my work. His guidance through the process provided an outsider perspective to my thoughts and enriched my understanding and communication of ideas.

I would like to also thank Dr. Deanne Otto, my dissertation committee member for her timely and thorough feedback. She looked at fine details that are easy to miss after innumerable edits that lead to developing a big picture focus.

Finally, I would like to thank the URR of my dissertation committee, Dr. Gary Lacy, for his encouraging comments and his interest in the topic I studied.

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Chapter 1: Introduction to the Study

Performance in high school science courses can be an early predictor of students' interest to pursue further education in science related fields. When students do not do well in high school science courses, they may no longer stay motivated to study science, which can consequently impact enrolment in science courses. Targeted intervention by teachers are helpful in supporting students who may be inadequately equipped to address shortcomings in their learning. These interventions may also inspire students to study science, which may in turn, help create a scientifically literate community. One approach of learning support for students is dialogic teaching, also known as argumentation, where students verbalize their thought process as they engage in dialogue with each other and with the teacher. Through the conversations, the instructor becomes aware of students' understanding and communication of ideas, and can modify the lesson to scaffold learners' understanding of concepts.

The purpose of this mixed methods concurrent nested study was to understand how teachers planned for and facilitated argumentation, and how argumentation consequently impacted student motivation in science class. The argumentative process starts with an open-ended question from a teacher that creates space for multiple responses from students; progresses with dialogic discourse that guides learners to arrive, through reasoning, at an evidence based response; and ends with providing learners with an experience similar to that of the complex practice of the scientific community of arriving at an understanding of concepts. The potential social change implication of this study is derived from understanding and providing examples of how teachers facilitated argumentation in science classrooms. I believe that my study findings are applicable to other teachers and contexts. My findings may also provide an impetus for science teachers' professional development, which has a direct bearing on student learning.

In Chapter 1, I introduce the various components of the study including the background, problem statement, purpose of the study, and conceptual framework. In addition, I state my research questions and applicable definitions and describe the nature, scope, and limitations of the study. I concluded the chapter by considering the significance of my investigation.

Background

Argumentation is a complex learning practice. It is "a social process of constructing, supporting, and critiquing claims with the objective of developing shared knowledge" (Manz, 2014, p. 2). In proposing, supporting, critiquing, refining, justifying, and defending their positions about specific scientific topic, students draw on higher-level critical-thinking skills (Llewellyn, 2013). For students to engage in argumentation, they need to know the content being discussed, feel comfortable presenting their ideas and evaluating multiple assertions made by their classmates, and have the skills to express disagreement with an idea without engaging in personal conflicts. The role of the teacher is therefore crucial in creating a supportive learning environment where negotiation of ideas is tolerated and its practice is nurtured (Bryan, Glyn, & Kittleson, 2011; Duit & Treagust, 2003; Gillet, Vallerand, & Lafreniere, 2012; Lavinge, Vallerand, & Miquelon, 2007).

In order to draw students into a conversation on a science principle or concept, a teacher has to be attentive to and use student responses (Ruiz-Primo & Furtak, 2007). The teacher should ask probing questions (Pimentel & McNeill, 2014) which provides a model for students to develop their own understanding of how content is questioned (Ford, 2008). In addition to providing feedback during instruction, adjusting ongoing teaching and learning (Heritage 2010; Minstrell, Anderson, & Li, 2011) and managing the duration over which confusion can prevail in students' minds before they lose interest in the class during discussions (D'Mello, Lehman, Pekrun, & Grasser, 2014) are essential skills for teachers to facilitate argumentation. In other words, a teacher must find a balance between correcting students' answers and allowing students to negotiate their thoughts to arrive at an answer during class discussions.

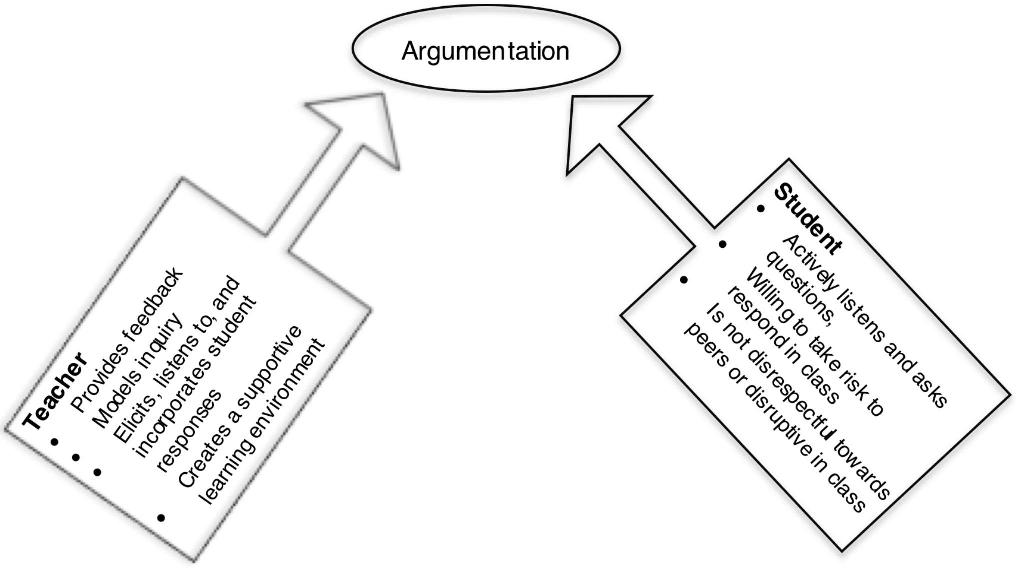

Figure 1. Teacher-student partnership during argumentation.

Argumentation thrives when teachers and students become partners in the teaching-learning process (see Figure 1). Informal formative feedback is the contribution from the teacher that starts argumentation (Ruiz-Primo & Furtak, 2007). As students think aloud, they contribute to the process by sharing ideas, evaluating competing explanations, refining their mental models, and arriving at a collective understanding based on application of principles of science (Berland & McNeill, 2010; Cynar & Bayraktar, 2014). The use of argumentation devolves authority of science from experts (i.e., books and teachers) and engages students in making meaning of concepts.

Researchers who have extensively studied teachers' use of argumentation have found evidence of improvement in student scores in science classes where argumentation is used compared to classes where argumentation is not used (Cinar & Bayraktar, 2014). However, based on my review of the literature, researchers have not adequately examined how teachers plan for facilitating argumentation in their classes. Although there is research on how to improve student motivation particularly from teacher practices, there is no research on student motivation in science classes where they engage in argumentation. Research on formative feedback has shown that formative feedback can increase student motivation (Black & William, 2004; Coffey, Hammer, Levin, & Grant, 2011; Ruiz-Primo & Frutak, 2007). But, teachers who provide formative feedback have reported that they lack the skills for "orchestrating sustained scientific talk" in their classes (Pimentel & McNeil, 2014, p. 381). There may be many reasons why teachers provide feedback but they have difficulty to facilitate argumentation. One reason could be that researchers do not know enough about what teachers need to do to provide conversational formative feedback that inspires students to engage purposefully in class. I sought to bridge this gap by studying how teachers facilitate argumentation and how argumentation consequently affects student motivation in science classes. The following subsections briefly summarize literature on the use of argumentation in science class and how it affects students' understanding, achievement, and student motivation.

The Impact of Argumentation on Student Achievement in Science Classes

Ruiz-Primo and Furtak (2007), developed the Elicit, Student responds, Recognize, Use (ESRU) model (see Appendix C) for analysis of classroom conversations. When they used this model to analyze classroom conversation of three 6th and 7th grade science teachers, they found that student performance increased significantly in the classes of teachers who had elicited, recognized, and used student thought processes during instruction. Pretest and posttest findings of 5th grade students' conceptual understanding of heat and matter improved significantly after they participated in an argumentation-based class (Cinar & Bayraktar, 2014). Based on this study, Cinar and Bayraktar (2014) recommended that further research be conducted on the implementation of strategies that might promote more student interest in science.

Argumentation as active learning. One reason for why argumentation has been found to improve student performance in science class is that argumentation is a form of active learning. Freeman et al. (2013) define active learning as a "process of learning through activities and/or discussions in class, as opposed to passively listening to an expert. It involves higher order thinking and usually involves group work" (p. 8412). In their meta-analysis of 225 studies that reported data on examination performance of students in active learning and traditional lecture classrooms characterized by exposition by the teacher that limited student activity to taking notes and/or asking occasional and unprompted questions of the instructor, active learning increased students' performance on examination by almost half a letter grade while traditional lecture approaches increased failure rates by 55% compared to active learning strategies. Based on these findings, Freeman et al. (2013) recommended using a constructivist approach of *ask, don't tell* in order to build student understanding of the material and their engagement in class.

Researchers encourage teachers to promote active learning. The theory of social constructivism in science education advances the idea that dialogue and active classroom participation are precursors to student motivation (Duit & Treagust, 2003). In a physics class discussion on matter, students' reasoning revealed major flaws in their understanding of concepts (Coffey et al., 2011). Instead of continuing with the lesson, the teacher decided to first address the gaps in students' foundational knowledge for the topic, leading to redefining the goals of the lesson. In another study, classroom discourse that discussed why "incorrect answers are incorrect" (Osborne, 2010, p. 464) helped students to develop an understanding of why the correct answer was correct, which possibly laid a foundation for students' understanding of more complex ideas. Hence, teachers who believed that engaging students in authentic scientific reasoning would have long-term benefits for their confidence in science used students' thoughts to direct classroom conversation and did not allow the pressure of syllabus coverage to hold them back from dialogic discourse in their classes.

Based on their study of two 10th grade science classes, Taylor, Dawson, and Fraser (1997) encouraged teachers interested in promoting constructivist learning to shift from an authoritative presence during class discussion to one where they allowed students to actively negotiate their thoughts. Allowing time for students to develop and support their reasoning may lead to quiet time in class when nothing is being said. This time may be beneficial for students to reflect on and to evaluate statements made during discussion.

Learning progressions in argumentation. In a qualitative study with ninth grade biology teachers who used the ESRU model to code student responses and their own follow up questions and comments, Furtak et al. (2008), found that teachers "primarily used re-voicing, reconstructing, checking, and asking for students to provide [the] underlying mechanism [for the argumentation]" (p. 26) as a means of feedback during instruction. The information that teachers gathered from student responses was used to "determine appropriate instructional steps within the unit" (p. 27). In other words, teacher learning from student classroom responses helped teachers to develop instruction to bridge the gap between lesson goals and students' learning.

Learning progressions is a term that describes the deliberate sequencing of teaching and learning expectations in stages of development, ages, or grade levels. Berland & McNeill (2010) developed learning progressions for argumentation that invited teachers to provide structure (examples of what counts as good evidence in scientific reasoning) in order to progressively engage students in argumentative discourse. These learning progressions can provided guidance to teachers in designing their instructions so that students' learning progresses towards clearly defined learning outcomes and classroom discourse leads to enhanced reasoning skills and conceptual understanding (Osborne, 2010), which in turn raises learner efficacy.

Transfer of argumentation skills across disciplines. Studies of the transfer of argumentation skills across disciplines shows, that although argumentation skills can be transferred across disciplines, there is an asymmetry with respect to transfer of skills (Iordanou, 2010; Kuhn, 2010). When argumentation skills were taught within a science context, students' ability to use the same skills in a social science context was stronger than when the skills were taught in the social science context and transferred to a science context. Iordanou (2010) and Kuhn (2010) therefore suggested that teachers particularly emphasize argumentation skills during science instruction given the specific nature of content in the sciences. Reasoning in science requires an integration of universal principles, laws, and theories, which have been developed through rigorous debate within the scientific community. Appeal to analogy and deductive reasoning in science are used for justification, as are experimental results, and therefore engaging students in dialogic discourse in a science class develops their argumentation skills universally.

Student Motivation in Science Class

Student motivation can be intrinsic (i.e., driven by an interest and the desire to learn a subject) or extrinsic (i.e., driven by a reward, generally in the form of good grades. Students may be unmotivated to study science; they may take science classes only because the courses are required to graduate. In the case of extrinsically motivated and unmotivated learners, the role of a teacher (and parents) is significant in sustaining student participation in science learning. A few significant factors that impact student motivation is science class are discussed below.

Teacher feedback. Formative assessment is a process (Heritage, 2010; Minstrell, Anderson, & Li, 2011; Ruiz-Primo & Furtak, 2007) used by teachers and students during instruction that provides feedback to adjust ongoing teaching and learning. Heritage (2010) distinguishes between the actual level of development a learner has reached and the potential level of development the learner is capable of reaching. He emphasizes the role of teacher's feedback in scaffolding learning by providing appropriate cognitive challenge to the learner, and also in building students' ability to self-monitor and self-regulate their learning. Teacher responsiveness through feedback, to student reasoning in addition to developing an understanding of students' preconceptions of science affects students' motivation to learn science (Atkin & Coffey, 2003; Coffey, Hammer, Levin, & Grant, 2011; Ruiz-Primo & Furtak, 2007).

Feedback in the form of scripts. Scripts are step-by-step guidelines to approaching problem solving, and unlike rubrics, do not contain grading parameters. In an experimental design, Panadero, Alonso-Tapia, and Reche (2013) found that scripts were more useful than assessment rubrics in promoting self-regulation and learning among pre service teachers. The analogy from the work of Panadero et al. (2013) that I have drawn for my study is that when teacher communication in the learning environment focuses on discipline specific language and processes, student competency to study the subject gets strong, which has a direct bearing on their self-efficacy and motivation. In a similar vein, I expect high school students' competency in science to improve if their teachers train them to integrate scientific reasoning during dialogic discourse.

Other- and self-efficacy. In their quantitative study to investigate middle school science students' active learning strategy, Tas and Cakir (2014) found that student self-efficacy was dependent on the belief of the parent and teacher in the students' ability of goal mastery. These students developed confidence in their ability to perform well in science activities, developed belief in the importance and utility of the science task, and consequently developed learning strategies to succeed in science. Arrepattamannil, Freeman, and Klinger (2011) examined the effect on science achievement (a) of motivation to learn science and (b) of instructional practices. Based on the study, they recommend that teachers work on student motivational factors, as students with high level of confidence perform science tasks, and students with a more positive perception of their ability to learn science, achieved higher in science than those who studied in classes with inquiry-based approaches. Hence, pedagogical practices that build student efficacy to handle a rigorous program led to demonstration of strong learning outcomes from students.

Collaborative learning. A mixed method study to understand high school students' motivation to study Advanced Placement (AP) science undertaken by Bryan, Glyn, and Kittleson (2011) showed that in addition to relevance of content, their grades in the course, and quality of classroom instruction; collaborative learning was identified by students as a strong motivator to enroll in advanced science courses. Students' identification of collaborative learning, underscores elements of argumentation where learners engaged with each other's thoughts in order to arrive at a collective understanding of the material.

Autonomy support. Supportive social environment of the classroom created as a result of autonomy given by teachers has a direct bearing on students' self-determination to study science. Lavigne, Vallerand, and Miquelon (2007), investigated students' motivation to study science (from 728, tenth grade French-Canadian students) on four sub-scales – need satisfaction, autonomy support, future intention, and demographic variables – on a science motivation questionnaire. They found that although future intention was a driving factor for initial enrolment in science, students who perceived greater autonomy support from their teachers performed stronger in science and expressed sustained interest in studying science in the future, as compared to students who perceived less autonomy support from their teachers. Gillet, Vallerand, and Lafreniere (2012) in their study found that despite an increased expectation of autonomy support as a consequence of a decrease in high school students' perception of autonomy support from parents and teacher (compared to earlier years), autonomy support led to a decrease in demotivation in high school students even when it did not increase their intrinsic motivation. When teachers and parents took into consideration the child's *perspective* and allowed the learner "choice in decision making while minimizing pressure" (p. 79) it fostered intrinsic motivation. Perspective in science instruction manifests within individual reasoning process and therefore enhances argumentation.

Finally, in spirit, this study is a response to Minstrell, Anderson, and Li's (2011) work on Building on Learner Thinking (BOLT). Minstrell et al., (2011, p. 12) advocate for an assessment process “that builds on learner thinking (which) can achieve positive and significant improvement in STEM learning… using carefully crafted curricular activities…and formative assessment to monitor learning progress and make adjustment in learning and instruction.” How do teachers plan for building on learner thinking? How do they actually provide structure, context and feedback? And, in this process, is there evidence that student motivation increases? In seeking answers to these questions, this study addressed the lack of research on how teachers facilitate argumentation and its consequent impact on student motivation.

My study analyzed teachers’ pedagogical approach to facilitating argumentation in their classes. In doing so, I sought to add to the literature regarding developing teachers’ use of argumentation in science education. Only when teachers see the value of dialogic discourse in student learning, will teachers be willing to transition from an authoritative classroom control to being instructionally responsive to their students. Additionally, an important outcome of my study will be an impetus for professional development of teachers for using curricular activities that engages students in evidence based arguments to develop collective understanding of concepts in their learners.

Statement of the Problem

Despite growing research on argumentation as a pedagogical tool for active learning that leads to increased understanding of material (Cinar & Bayraktar, 2014; Coffey et al., 2011; Duit & Treagust, 2003; Freeman, et al., 2013; Kuhn, 2010; Osborne, 2013; Pimentel & McNeill, 2014) its use by teachers outside the realm of professional development and educational research is limited. Studies on student motivation have looked at autonomy support (Gillet, Vallerand, & Lafreniere, 2012; Lavigne, Vallerand, & Miquelon 2007) learner efficacy (Arrepattamannil, Freeman, & Klinger, 2011; Tas & Cakir, 2014), collaborative learning (Bryan, Glyn, & Kittleson, 2011) and feedback from teachers (Brown, Harris, & Harnett, 2012) to enhance student performance but overlooked the use of argumentation on student motivation.

The problem this study attempted to understand is how teachers planned for and facilitated argumentation, and how student motivation changed in the science class as a consequence of participation in argumentation.

Purpose of the Study

The purpose of my mixed methods, concurrent nested study was to understand how science teachers planned for and facilitated argumentation, and to explore how student motivation in science classes changed as a consequence of participation in argumentation. Although there is literature on improvement in student's science performance as a result of engaging in argumentation and as a result of motivation to study science, there is little knowledge about teachers' conception and facilitation of argumentation within the "pluralistic and multifaceted" (Rudolph, 2014, p. 37) methods of knowledge growth in science and its possible impact on student motivation.

Interviews with teachers gathered information about their understanding of argumentation and how they planned to facilitate argumentation in their classes. I observed teachers' facilitation of argumentation during class and took extensive notes of classroom instruction for analysis, discussion, and description of the process of argumentation during instruction.

Quantitative results based on students' responses to the Students' Motivation Towards Science Learning (SMTSL) instrument (Tuan, Chi-Chin, & Shyang-Horng, 2005) measured student motivation in science class, both pre intervention and post intervention. Pedagogical practice of argumentation is the independent variable and student motivation is the dependent variable. Student gender and teacher reported student performance levels are covariates in the study.

While the qualitative data analyzed the process of argumentation as facilitated by the teacher, quantitative data in this mixed-method, expanded our understanding (Greene, Caracelli, & Graham, 1989) of argumentation by studying its impact on one learning outcome – student motivation.

Research Question

How does the use of argumentation in science instruction motivate students in science classes? This one question was divided into sub-questions:

Qualitative questions:

RQ1. How do teachers plan to incorporate argumentation in their instruction?

RQ2. How does argumentation occur in the classroom in terms of epistemic operators?

Quantitative question:

RQ3. To what extent does student motivation in the science class change after engaging in argumentation in class?

H_o1: There is no change in student motivation before and after they engage in argumentation in class.

H$_a$1: There is a change in student motivation in science class after argumentation has been introduced to classroom instruction.

Interviews with teachers regarding their process of development and design of their lesson plan to facilitate argumentation provided data to answer the first qualitative research question. Notes from observation of classroom discourse provided data to answer the second qualitative question. Student responses on the SMTSL instrument (Tuan, Chi-Chin, & Shyang-Horng, 2005) provided data pre and post intervention to answer the quantitative question. The six constructs of motivation on the SMTSL instrument are: self-efficacy, active learning strategies, science learning values, achievement goal, performance goal, and learning environment stimulation.

Conceptual and Theoretical Framework

Concepts of argumentation and formative feedback within current refereed literature, along with Bandura's social cognitive theory (with particular attention to motivation) grounded this study. Formative feedback is "all those activities undertaken by the teacher to modify the teaching and learning activities in which they engage students" (Trumbull & Lash, 2013, p. 2). It is not a one shot event, but is generally comprised of a series of student response – teacher question/comment, that "builds on students' learning" (Pimentel & McNeill, 2013, p. 372), and progressively increases understanding – for students of the material being studied, and for the teacher about student learning (Berland & McNeill, 2010; Coffey, Hammer & Levin, 2011; Duit & Treagust, 1998). Task specific feedback in particular, leads to maximum gains in learning (Heritage, 2010). Argumentation is a form of task specific, informal formative feedback

(Ruiz-Prim & Furtak, 2007) as it contains all the elements of feedback: student's response, teacher's comment/probing question, dialogue that generates ideas, students' critique of these ideas, teacher's formalization of questions based on student comments to uncover student thought process, and eventually learners' arrival at an understanding of the material with the help of the teacher. Although feedback is generally perceived as unidirectional (teacher to student), argumentation is bidirectional (student to teacher, and teacher to student). This reciprocity within argumentation makes it a robust form of feedback and therefore I decided to analyze classroom discourse through the conceptual framework of argumentation.

Although teachers facilitate argumentation, as stated in the background section students are participants in the learning process through dialogue with the teacher and with other students in class within the context of the instruction (and the discipline). For argumentation to be an effective pedagogy for learning, *framing* (Berland & Hammer, 2012) students' experience so they understand the purpose of argumentation to their learning is essential. Duschl (2008) talks of a three part harmony, "balancing cognitive, epistemic, and social learning goals" (p. 1) during argumentation in order to build agency of the learner to take ownership for their learning.

Agentic individuals participate in their learning with intentionality, forethought, self-reflection, and through self-regulation (Bandura, 1999). They exercise control on their experiences while at the same time letting these experiences shape their cognitive growth, change their motivation, and eventually lead to self-determined effort (Ryan & Deci, 1998). According to social cognitive learning theory motivation is dependent on individual’s thought, which influences their participation in learning. Social cognitive theory (elaborated further in chapter 2) is vital to understand the dynamics of the teacher’s facilitation of argumentation - the context of the classroom that lays the rules of engagement, and the disciplinary content of science – in order to see its impact on learner’s motivation in science class.

The six constructs of motivation in Students’ Motivation Towards Science Learning (SMTSL) instrument (Tuan, Chi-Chin, & Shyang-Horng, 2005): self-efficacy, active learning strategies, science learning value, performance goal, achievement goal, and learning environment stimulation; tie together social, discipline specific, and learner (personal) traits to their effort in class. The correlation between teachers’ facilitation of argumentation and students’ needs, can lead to different level of change in motivation on each of the constructs on the motivation scale, which this study will analyze. The validity of the SMTSL instrument (Tuan, Chi-Chin, & Shyang-Horng, 2005) and its use in other studies is discussed in chapter 2.

The conceptual framework of argumentation is informed by works of Erduran, Simon, & Osborne (2004) who adapted Toulmin’s Argumentation Pattern (1958) to quantify argumentation in science classes. Jiménez-Aleixandre, Rodríguez, & Duschl, (1999) developed epistemic operations to identify the scientific (example: analogy, deduction, induction, appeal to consistency) nature of warrants, claims, and backing (TAP features) in scientific reasoning during argumentation. Ruiz-Primo & Furtak’s ESRU model will be used to code how teachers worded their questions in response to student answers.

Nature of the Study

The three research questions, which ask how teachers plan to incorporate argumentation in their instruction, how that argumentation actually occurs in terms of teacher and student utterances and discourse, as well as how much—if at all—student motivation changes in the science classroom, dictated the choice of the mixed methods concurrent nested design. In understanding argumentation, it was important to include the voice of students as they reflected on their experience of participating in argumentation. The qualitative questions attempted to understand the process of argumentation and the quantitative question focused on the outcome of the process—motivation change as a consequence of participation in argumentation. One common purpose of mixed methods studies is to use the results from one approach to elaborate or enhance the results from the other approach. However, my study aimed to "extend the scope, breadth, and range" (Greene, Caracelli, & Graham, 1989, p. 269) of understanding of argumentation by looking at it from the perspective of students (motivation scale response) and the practice of teachers.

The word "effect" in the question suggests effect of treatment, but I did not explore a cause-effect relationship in the mixed method. In fact, neither quantitative data was collected based on learning from qualitative data, nor collection of qualitative data was determined by quantitative results. The independence of data collection for qualitative and the quantitative questions to answer separate questions justifies a concurrent data collection from both set of participants in the process of argumentation – student and teacher – each of whom provided a different perspective for the study. Mixed methods evaluation approaches where "a short quantitative method (pre–post measure) is paired with a longer qualitative method…is called bracketed timing" (Greene, Caracelli, & Graham, 1989, p. 264) and falls somewhere along the continuum from sequential to concurrent.

Unlike many mixed methods studies that collect qualitative and quantitative data from the same set of participants, I collected qualitative (facilitating argumentation – process) data from teachers, and quantitative (motivation scale – learning outcome) data from students. This kind of mixed methods approach where qualitative and quantitative data is collected from different participants is common in program evaluation (Pluye, Grad, Levine, & Nicolau, 2009). At some level studying changes in student motivation as a consequence of participation in argumentation is evaluative of teachers' pedagogy and hence justifies using data for one question (qualitative) from teachers and for another question (quantitative) from students. Qualitative data from teachers helped to understand how they facilitated argumentation, including their understanding of what argumentation means and entails, and their planning process of using argumentation; and quantitative data from students collected on the SMTSL instrument provided their perception of changes in their motivation. The two data sets were integrated during the discussion and interpretation of findings phase, in order to get a comprehensive understanding of argumentation.

Although I compared the findings from the qualitative and the quantitative parts of the study to see if the conclusion from one supported that from the other (Ostlund, Kidd, Wengstrom, & Rowa-Dewar, 2011; Palinkas, et al., 2013) I have not attempted to converge the results from qualitative and quantitative questions. Divergence between qualitative and quantitative data in mixed methods study can lead to a "depth of understanding" (Pluye, Grad, Levine, & Nicolau, 2009, p. 63) and that the whole is larger than the sum of its parts.

In this nested design quantitative data is secondary to the qualitative data on argumentation. While the qualitative data answers the primary question on argumentation facilitation, the secondary quantitative data answers a different question from a different stakeholder in the study. Student motivation scales were analyzed using inferential statistics on each of the constructs of motivation. I am interested in understanding whether students find the process of argumentation motivating in their science class and how teachers engage students' thought process during argumentation.

Although I observed the classes of teachers who were trying an instructional approach – argumentation – my study does not fall under any of the major qualitative research categories: case study, phenomenology, ethnography, and grounded research (Creswell, 2006). My question focuses on what teachers do in class and not on the characteristics of the participants (teacher and student) or of argumentation, a concept that is still being studied by researchers to make it a common practice in science classrooms. I took thorough notes of class events and interviewed teachers but my observation and analysis did not translate into developing a theory (my study cannot be generalized for all schools and classes) or understanding a phenomenon completely. It is not a case study because I did not describe the experience of teachers or students. Additionally, it is not action research as neither the participants nor I attempted to address an immediate problem. Besides, even though teachers attempted to intentionally use argumentation in class the exercise was exploratory in nature.

The four grade nine science teachers who planned and facilitated argumentation in their classes provided an information-rich site for inquiry. The number of teachers for the study was limited to four for practical reasons: data collection occurred multiple times for each teacher—almost four hours per grade nine science cohort section, which provided sufficient data to analyze classroom discourse. In purposefully selecting four teachers for this study, I emulated other research that analyzes classroom discourse for argumentation (Palinkas et al., 2013).

Summary of methodology. The school undertakes evaluation of classroom instruction periodically and collects student responses on survey instruments regularly in order to make decisions about its programs. The school took ownership of implementing the SMTSL instrument (Tuan, Chi-Chin, & Shyang-Horng, 2005) to all its high school students as part of its ongoing assessment of students' motivation in science classes. Teachers collaborate and work collegially to keep the pace of syllabus coverage uniform across all sections of a course. Additionally, the school supports teachers' pedagogical initiatives that promote student engagement in learning.

One-on-one interview with each of the four ninth grade science teachers was the first set of qualitative data collected. I interviewed teachers to understand how they planned to facilitate argumentation in their classes. Interview questions are included in Appendix D. In order to accommodate my study, the school agreed to collect student responses on the SMTSL instrument as pre intervention (pre implementation of argumentation in class) quantitative data immediately following teacher interviews. Hence the first set of pre intervention quantitative and qualitative data was collected simultaneously - the quantitative data provided by the school as part of the school's assessment of student motivation in their science class and qualitative data I collected from teacher interview.

Following the interview with all teachers, I sat in classes and took extensive notes of classroom discourse for each of the three ninth grade science classes over the period of one week (approximately four hours of instruction time per class, giving a total of twelve hours of instruction time) as students engaged in argumentation. The focus was on teachers' utterances - questions that initiated student response, and teachers' use of student response. Finally, the school collected a post intervention student survey response to the SMTSL instrument and provided me the de-identified but matched pre and post intervention data. Since the school has a practice of teachers siting in each other's classes my presence in class was not a new or intrusive process.

Notes of classroom conversation for the entire week of observation were categorized in real time (see Appendix E), into TP - teacher presentation, AD - teacher guided authoritative discussion, DD - teacher guided dialogic discussion, and SI - student initiation) to understand the rhythm of the discourse (Nurkka, Viiri, Littleton, & Lehesvuori, 2014). Analysis of each segment of DD - teacher guided dialogic discussion or "argument space" (p. 10) provided information about "TAPping of argumentation" (Erduran, Simon, & Osborne, 2004). Since argumentation in a science class was analyzed it was essential that epistemic operators (Jiménez-Aleixandre, Rodríguez, & Duschl,

1999) specific to the discipline were used to identify warrants, claims, and backing (TAP features) in scientific reasoning during argumentation. Finally, the ESRU model (Ruiz-Primo & Furtak, 2007) helped to focus on teacher utterances – how they worded their questions and comments to engage students in conversations in class. A protocol for qualitative data analysis is included in Appendix F. Qualitative analysis of classroom talk or discourse is extensive and it helped me understand how the teacher facilitated argumentation during instruction.

I shared via Skype conference call my analysis of classroom discourse with each teacher. Teacher interview data are documented and notes of classroom observation are saved and used for analysis of teachers' understanding of and use of argumentation in their instruction.

Inferential statistical analysis of student response to the SMTSL questionnaire pre and post intervention provided information to help indicate changes in motivation (if any) for the entire group, by gender, and by achievement level (defined by grade boundaries). Statistical tests included the following non-parametric tests: The Wilcoxon Signed Rank test for difference in mean for the entire group, Mann-Whitney U-test for difference in means pre and post intervention by gender, the Mann-Whitney U-test for ANOVA on the variation of means of low, middle, and high achievers, pre and post intervention, and multiple linear regression model on the difference scores with qualitative predictor of gender and achievement. The covariates in the quantitative study are student gender and achievement level (defined by grade boundaries).

Most of the 90 ninth grade students had similar content background in science as they had studied at this school from elementary classes, but they represented a range of ability level of performance in the science class, which made the group heterogeneous with respect to their possible interest in the subject. Although students in the school (and therefore in the class) came from a range of socio-economic backgrounds, they all valued strong academic performance as a prerequisite for upward social mobility.

Definition of Terms

I used the following definitions for key terms in this study:

Argumentation: “a social process of constructing, supporting, and critiquing claims with the objective of developing shared knowledge” (Manz, 2014, p. 2). Argumentation draws on higher-level, critical-thinking skills as students propose, support, critique, refine, justify, and defend their positions about a specific scientific topic.

Epistemic conversation or *disciplinary substance of conversation* is one where students justify their claims by using science principles. They ask questions, provide responses, raise doubts, evaluate alternate explanations, and then arrive at an answer validated by principles of science. The emphasis on principles of science underscores the nature of knowledge within the discipline of science. *Epistemic practices* ground authority for knowledge in the discipline (Chinn & Brewer, 1993; Manz, 2014; Toulmin, 1958) and epistemic or scientific conversations contribute to the literature on argumentation as “discipline specific target of instruction, a process that provides students access to scientific ways of knowing, thinking, and acting.” (Manz, 2014, p. 3).

The definitions of the terms epistemic conversation, argumentation, and scientific inquiry overlap with respect to demonstration of skills and practices to learn science, but for the purpose of this study I will use the term argumentation to represent disciplinary substance of conversation and epistemic practices in a high school science classroom.

Feedback is information with which a learner can "confirm, add to, overwrite, tune, or restructure information in memory, whether that information is domain knowledge, meta-cognitive knowledge, belief about self and tasks, or cognitive tactics and strategies" (Winne & Butler,1994, as cited in Hattie & Timperlie, 2007, p. 82).

Informal formative assessment or *assessment conversation* refers to daily instructional dialogue in the class within a group setting or one-on-one that allow teacher to "gather information about the status of students' conceptions, mental models, strategies, language use, or communication skills" to inform instruction (Ruiz-Primo & Furtak, 2007, p. 60).

Inquiry based teaching: Scientific inquiry that requires students to draw on their scientific knowledge to "ask scientifically oriented questions, collect and analyze data from scientific investigations, develop and communicate explanations of scientific phenomena…" (Furtak, Seidel, Iverson, & Briggs, 2012, p. 301).

Motivation is defined in social cognitive theory as "an internal state that arouses, directs, and sustains goal directed behavior" (Bryan, Glynn, & Kittleson, 2011, p. 1050).

Assumptions

My assumptions for the study are

(1) The four science teachers are familiar with the characteristics of argumentation and appreciate its value as a pedagogic practice in class

(2) The four science teachers believe that their classroom practice can engage learners and motivate the learner to study science despite students' interest or lack of interest in science (Turturean, 2013).

(3) The science teachers' background in the discipline and in educational pedagogy is an asset for them as they developed, implemented, and refined their dialogic approach in class. If a teacher lacks the academic background in the discipline it is difficult for him/her to engage students in a deep conversation about the topic. Additionally, a teacher who is an expert in his/her subject but who lacks an understanding of how students learn may follow instructional practices that don't meet the needs of diverse learners. These teachers may get some students to do the work, but students may not develop skills and knowledge to succeed in the course. Hence, teacher expertise in subject matter and pedagogy is crucial for effectively using skills of epistemic conversations in class. Furthermore, an understanding among teachers, of the nature of science as a body of knowledge that has emerged both through experimentation and argumentation will help teachers practice the skill of argumentation along with the activities and labs that students engage in. The dialogic approach is not a substitute to existing pedagogies in science but complements the repertoire of instructional practices of

the teacher. There may be students who despite their knowledge are unable to communicate effectively and/or verbally support their reasoning. A range of instructional and assessment approaches will help to support the teaching-learning dynamic in the classroom.

(4) The four science teachers at the school work well collaboratively and were open to professional engagement with colleagues. They will be open to feedback from each other and from me (when I share my research findings with them). I did not have a professional influence on the teachers and teachers' contribution to my dissertation on argumentation was a reflection of their commitment to the pedagogical approach.

(5) Finally, for the quantitative part of the study. I assumed that students will be thoughtful and honest when they respond to the motivation instrument, and that the school will administer the instrument at a time so that it does not bias student responses.

Scope of the Study

This study was undertaken in a ninth grade general science classroom in New Delhi, India. All students in the science class had met the prerequisite for the course. Students brought a range of academic skills and motivation to study science. They came from a range of socio-economic background. Each general science class was team taught by two teachers – one with an advanced degree in physical science and the other with an advanced degree in biological science – who also had a degree in education. The syllabus for this general science program was developed by, the Central Board of Secondary

Education (CBSE) (http://www.cbse.nic.in/cce/cce-manual/CBSE-FA-Class-IX%20(Science)%20Final.pdf) which encourages and supports formative assessment in science instruction. Hence, this study used a syllabus developed through extensive research on science education taught in a classroom where teachers had a post graduate degree in the discipline and a graduate degree in education. The range of learner socio-economic backgrounds, abilities, and motivations, provided a platform to test the impact of dialogic approach of instruction on student motivation. The results of this study should be applicable in classroom environments of heterogeneous learners and where teachers because of their advanced degree in the discipline and in education have the potential to engage students in disciplinary conversations or argumentation. With gender and student achievement (defined by grade boundaries) as covariates the statistical analysis of quantitative data addressed issues of internal validity. Findings from this study are transferable only to situation with a heterogeneous set of learners and where teachers are comfortable facilitating argumentation.

The study did not assume that motivation translates to higher academic performance. Some students may not be motivated but they may do well on tests while others may be interested in and motivated by science ideas but they don’t prepare adequately or don’t test well. A longitudinal study that focuses on impact of engaging in argumentation on changes in students’ academic performance will be helpful.

Assessment of student learning is an area that has not been discussed in this research. When assessment evolves along with changes in pedagogy, new pedagogical approaches are sustainable. Whether every classroom interaction must lead to a tangible evaluative outcome is a question that can be explored further. The joy of learning cannot be assigned a numerical value. It is an emotional state that brings its own returns to personal development.

Limitations

Since the study was undertaken at a day school there is a possibility that daily attendance to school varied and there were students who did not get the entire benefit of the intervention. Changes in their motivation, if any, may not be a result of the intervention. Additionally, of the entire high school population, the study focused on grade 9 teachers and students. Transferability to other grades (10th, 11th, and 12th) in the school may be limited due to the fact that 10th and 12th grade students focus on preparing for the state exam, and 11th & 12th grade students have specialized into studying science, business, and humanities for their post-secondary years and therefore are naturally interested in the courses they take. Furthermore, the results may not be reproducible in environments where teachers are not experts in their subject or do not understand argumentation. In other words, teachers may ask probing questions but if they lack the depth of knowledge of content the teachers may not be able to identify conceptual flaws in student reasoning and therefore the teacher may be unable to use and build on student responses for effective use of argumentation in instruction. Teachers who lack disciplinary knowledge may be able to focus on the process of argumentation as outlined by Toulmin (1958), but may not be able to evaluate the content of arguments. This limitation of teachers’ knowledge of content and pedagogy can be addressed by assigning teachers who have degrees in the discipline they teach, for high school students.

The SMTSL instrument used student self-reported perceptions that may be influenced by events other than students' experience in the science class. Additionally, students' propensity for a particular science (biology, physics, chemistry) could change their motivation on the science motivation scale. This limitation can be addressed by conducting another study on student motivation for each sub disciplines of science to see if student motivation varies between biology, chemistry, physics, and environmental/health science.

Since (a) I believed that argumentation complements the repertoire of pedagogical approaches in a science class (b) I understood that the level of argumentation can vary by topic, and (c) I accepted that teachers facilitate argumentation differently based on their preference and skill, I was not biased towards any one approach to facilitating argumentation. Adopting specific approaches (ESRU (Ruiz-Primo & Furtak, 2007; rhythm of discourse by Nurkka, Viiri, Littleton, & Lehesvuori, 2014; TAPping by Erduran, Simon, & Osborne, 2004; and epistemic operators by Jiménez-Aleixandre, Rodríguez, & Duschl, 1999) to analyze classroom conversation helped to maintain consistency in analysis of qualitative data across all sections of the course.

Significance of the Study

This mixed-methods concurrent nested study underscores the value of argumentation in science classrooms. Teachers' understanding of *what* students know, *how* they know what they know, *why* they believe what they know, and how they effectively *communicate* their knowledge; and students' engagement in their learning by articulating their thoughts and integrating principles of science in their responses;

cumulatively contributed to an understanding of argumentation and its role in instruction in a ninth grade science class.

In addition to understanding how curricular feedback embedded in science instructions –argumentation – impacts student motivation and self-determination for effective learning in science, the study underscored the nature of scientific inquiry as a socio-constructivist process similar to learning in the humanities, and added to the debate on issues related to transferability of skills across disciplines. Additionally, through the development and implementation of the intervention teachers focused on their classroom conversation with students, as they intentionally integrated the pedagogy of argumentation – an opportunity for teacher professional development. Furthermore, the study provides examples of how teachers facilitated argumentation in their class and adds to the resource that other science teachers can draw on.

The study holds tremendous potential at the micro (student classroom engagement and teacher collegiality), macro (teacher professional development and learner/student self-regulation) and mega (science education) levels as it provides a critique of classroom use of argumentation and develops skills for two primary stakeholders in the teaching-learning context – the student and the teacher – to engage in argumentation for learning.

Summary

In this chapter I introduced the various components of the study including the background, problem statement, purpose of the study, and conceptual framework. In addition, research questions and applicable definitions, along with the nature, scope, limitations, and significance of the study appear in this chapter.

In the background to the study in addition to elaborating current debate on argumentation in science classes, I presented argumentation as a form of informal formative feedback, and I identified a gap in current literature on the effect of argumentation on student motivation in science class. I listed techniques used in earlier studies to analyze argumentation (qualitative data) in science classes, and identified statistical analysis for the de-identified quantitative data on SMTSL instrument that the school provided. Constraints of adopting the pedagogy of argumentation – time, teachers' inability to orchestrate argumentation, and possibly because many students tend to focus more on grades than on learning – were acknowledged. Considering that argumentation is an active learning approach that can help to address misconceptions as teachers provide formative feedback during classroom instruction and students evaluate multiple responses to collectively arrive at conceptual understanding, its benefit for students was also acknowledged. Issues of generalizability and transferability of the study were discussed within the context of scope and limitations of the study, especially since this study was undertaken at a school where science teachers collaborated to encourage more dialogue from students in their classes, and collected data to study the effect of their effort to use argumentation during instruction. Finally, a brief discussion about bias made me aware of its potential impact on data collection and analysis.

In chapter 2, I review the literature survey strategy and explain the conceptual framework in greater detail. I also discuss the nature of argumentation in science along with the social-cognitive theory of learning in the sciences.

Chapter 2: Literature Review

My study aimed to understand how teachers planned for and facilitated argumentation, and changes in student motivation in the science class as a consequence of participation in argumentation. Since conversation is a reciprocal process that requires participants to engage with one another's ideas, dialogic learning is best explained by understanding the dynamics of processing information to generate thoughts in the mind and to effectively communicate them via words (Berland & McNeil, 2010; Cinar & Bayraktar, 2014). However, in an academic setting, particularly in science, not all conversations count as argumentation.

Argumentation starts with a teacher's use of a student response. The teacher may ask a follow-up, probing question, or provide oral feedback with the objective of encouraging students to reflect, elaborate, and/or evaluate alternate explanations within the context of scientific principles (Ruiz-Primo & Furtak, 2007). Although the teacher facilitates argumentation, the student is integral to sustaining conversation in class (Furtak, Seidel, Iverson, & Briggs, 2012; Hattie & Timperlie, 2007). Almost all research on the value of argumentation in science classes has analyzed characteristics of classroom conversation using epistemic criteria (see Jiménez-Aleixandre, Rodríguez, & Duschl, 1999). Some researchers have documented improvement in student performance and understanding as a consequence of their participation in argumentation during class (Furtak, Seidel, Iverson, & Briggs, 2012). But, based on my review of the literature, no study has investigated consequent changes in student motivation. Formative feedback is considered as a motivator in student learning (Atkin & Coffey, 2003; Coffey, Ruiz-Primo

& Frutak, 2007; Gillet, Vallerand, & Lafreniere, 2012; Hammer, Levin, & Grant, 2011; Koballa, 2013; Minstrell, Anderson, & Li, 2011; Panadero, Alonso-Tapia, & Reche, 2013) along with supportive learning environments (Bryan, Glyn, & Kittleson, 2011).

But, if argumentation is informal formative feedback, then exploring its possible impact on motivation is a gap in research that my concurrent nested mixed methods study wishes to explore. The purpose of the study was to develop a better understanding of how science teachers plan for and facilitate argumentation in their classes, and explore whether teachers' use of argumentation had any impact on student motivation. In this chapter, I describe my strategies for searching literature related to the study. The section on conceptual and theoretical framework follows with an elaborate description (based on my research on argumentation) to justify the conceptual framework of argumentation for qualitative data and the theoretical framework of Bandura's (1989) social cognitive theory of learning to help us understand student learning within the context of the classroom. I devote a section to the construct of motivation in order to understand it better. Motivation is the dependent variable in the quantitative part of my mixed methods study. In discussing argumentation, I explore the challenges of using argumentation in science class. The literature is wrapped up with a section that brings together social cognitive theory (theoretical framework) and argumentation (conceptual framework) for science learning. I then summarize the ideas discussed in this chapter.

Literature Search Strategy

I accessed Google Scholar through the Walden University Library to search for relevant literature. Thoreau, the multiple database search tool, was particularly helpful in broadening access to articles through various databases. I followed up each database with a more in depth search for additional articles related to my topic. I limited my search to a period of 5 years prior to the date of start of my dissertation, so that I accessed latest developments in the field of my study. As I read a research paper I read seminal works citied in the paper and read other research that had cited the article I was reading, leading to a snowball effect in article selection.

My search terms focused on the concepts and their analogues identified in the title of my dissertation: *argumentation*, *classroom conversation*, *epistemic conversation*, *guided inquiry*, *feedback, formative assessment*, *student performance*, *motivation*, *science motivation*, *theories of learning*, and *professional learning communities*. Various combinations of these terms, for example, combining feedback and motivation, feedback and student performance, combining professional learning communities and self-regulation, and finally combining argumentation with science motivation and student performance, were also used to explore the interdependence between the variables.

I found many articles on argumentation and student performance but no articles on argumentation and science motivation or on epistemic conversation and science motivation. Additionally, most research on dialogic teaching in science used argumentation as a concept because epistemic is identified with practice of the scientific community that generates knowledge as opposed to work done by students who verify or *discover* established knowledge. I, therefore, decided not to focus on the word epistemic, but rather used argumentation to represent students' modeling the practice of the scientific community, as they used science principles to evaluate multiple claims in order to arrive at the most plausible answer within the social context of their classroom.

I also searched for articles on research methodology and theories of learning. Although I was aware that I would focus on social cognitive theory, I was interested in reviewing other theories on learning--for example, constructivist theory and online learning--that are a subset of social cognitive theory. Under research methodology I focused on mixed methods paradigm to guide my research design with qualitative and quantitative sub questions. When the information in the articles I was accessing started to saturate and became repetitive both in terms of information and citing similar sources, I scaled down my literature search.

Conceptual and Theoretical Framework

I used mixed methods approach for this study. I used different data sets to answer the questions for the quantitative and qualitative parts of my study. The focus of the qualitative part of my study was on teacher plan and facilitation of argumentation while the focus of the quantitative part was on examining changes in student motivation as a consequence of participation in argumentation. I therefore have a conceptual framework for the qualitative question to discuss argumentation and a theoretical framework for the quantitative section to understand student motivation within the social and epistemic context in science class.

The conceptual framework used in the studies that have informed my research is outlined here. Erduran, Simon, & Osborne (2004) provided a theoretical background to argumentation and they then elaborated on Toulmin Argumentation Pattern (TAP) to adapt it for analyzing teacher mediated argumentation and rebuttals in student group discussions. Conceptual change framework was used by Duit and Treagust (1998) and Coffey, Hammer, and Levin (2011). While Duit and Treagust (1998) analyzed classroom feedback for improved performance of students; Coffey, Hammer, and Levin (2011) encouraged a multi-dimensional approach to learning for understanding. Berland and Hammer (2012) used the conceptual framework of “framing” conversation which outlines teacher and student understanding of the purpose and process of argumentation within the social framework of the class, while Berland and McNeill (2010) used the conceptual framework of learning progressions to develop student argumentation and used epistemic criteria to analyze classroom conversation. Ford and Wargo (2011) used the scaffolding framework for instructional support in their study to analyze classroom conversation of a science unit for conceptual and epistemic argumentation. Minstrell, Anderson, and Li (2011) compared two formative assessment cycles: teacher and teaching focused vs. learner and learning focused to emphasize the value of assessment that “builds on student thinking” as the researchers evaluated classroom conversation (and its impact on student performance) using criteria similar to Ruiz-Primo and Furtak’s ESRU model. Cinar and Bayaktar (2014) discussed elements of argumentation (TAP) as a conceptual framework for their multiple case-study of looking at effect of argumentation on student performance. Freeman et al., (2014) used the conceptual approach of constructivist vs. exposition based instruction, to emphasize that formative feedback that builds on student thinking improves students’ learning outcome, based on his meta-analysis of existing literature.

The successful use of a range of frameworks in the refereed literature to understand argumentation in the classroom are closely linked to learning theories that identify argumentation as a "social process of constructing, supporting, and critiquing claims with the purpose of developing shared knowledge" (Manz, 2014, p. 3). I decided to use social cognitive theory of learning for my study as it is an overarching theory that encompasses ideas discussed in the frameworks of conceptual change (Berland & Hammer, 2012; Duit & Treagust, 2003; Coffey, Hammer, & Levin, 2011), learning progressions (Berland &McNeill, 2010), constructivist learning (Freeman, et al., 2014), and formative feedback (Ford & Wargo, 2011; Minstrell, Anderson, & Li, 2011); and engages learners in the process of learning. As stated in Chapter 1, the learner is a partner along with the teacher during argumentation. Social cognitive theory helps us understand how to meaningfully engage learners during argumentation in class.

Erduran, Simon, and Osborne (2004) and Cinar and Bayraktar (2014) elaborated on the TAP model to analyze argumentation and to support its use in teaching science. Additionally, Nurrka, Virri, Littleton, and Lehesvuori (2014) and Iordonu (2010) used argumentation as a construct for analyzing science classroom discourse. Duschl (2008) and Manz (2014) both elaborated on argumentation theory and emphasized the development of "epistemic cultures" within the context of the classroom that provides students with a filtered experience of the work that scientists do. However, I decided not to use argumentation theory because of the following reasons: (a) it is difficult to set up true argumentation in a high school classroom similar to the exercise of the scientific community. Unlike scientists who have spent years studying the topic they debate, students lack the theoretical background and the conviction of the validity of their work. (b) schools and classes are structured towards socializing the child to the system – completing tasks and achieving learning outcomes. Social dynamics in classrooms to a large extent continues to endorse teacher as the authoritative figure and requires compliance from students in procedural matters like completing homework, preparing for tests, and following class rules. Hence, student autonomy is staged and it is still constrained. (c) designing learning environments to facilitate argumentation is challenging for many teachers. The three general forms of argumentation (Jiménez-Aleixandre, Rodríguez, & Duschl, 1999) - analytical (grounded in theory of logic), dialectical (involves reasoning with premises that are not easily evident), and rhetorical (focus on persuasive reasoning) – make the process of *teaching* argumentation complex at the high school science context. It is best left for a more evolved state of learning.

I decided to use argumentation as the conceptual framework to analyze classroom discourse and its impact on student learning within the theory of learning provided by Socio Cognitive theory.

Conceptual Framework: Argumentation (and learning) in Science

The generation, justification, and application of knowledge guide scientific inquiry. Theories in science arise as a result of debates, evaluation of counter claims, and resolution of disagreements among scientists. The nature of science as a tentative body of knowledge that is empirically based and embedded in the social and cultural context (Manz, 2014; Duschl, 1999) underscores the significance of communication and dialogue during learning, as well as active student participation in the process of building their knowledge (Lederman & Abd-El-Khalick, n.d. Meyer & Crawford, 2011).

Learning in science is not limited to extending content knowledge, but requires students to develop a way of thinking and explaining the natural world that may not always overlap with their commonsense experience (Pimentel & McNeill, 2013). Students acquire specific vocabulary (scientific), symbols, diagrams, graphs, and equations that are used to communicate ideas and allow their mental models to evolve as they communicate their thoughts – in writing and verbally – with others in the class. Additionally, participating in a discourse within the context of the task allows for co-construction of scientific knowledge during the lesson (Berland & Hammer, 2012).

Teaching students the skills of argumentation in scientific reasoning includes making choice between theories that help to explain their scientific claims and presenting arguments to defend these claims. Argumentation is therefore about understanding the communication of moving from "evidence to explanation and premise to conclusion" (p. 759) or the failure to do so (Jiménez-Aleixandre, Rodríguez & Duschl, 1999).

Merely engaging in a dialogue in class does not guarantee that students will understand concepts and achieve learning outcomes (Ford & Wargo, 2011) since explanations require epistemic understanding of integrating principles of science. By following an intentional pedagogical practice of classroom discourse the teacher can engage learners to build their understanding and efficacy to study science (Aguiar, Mortimer, & Scott, 2010; Coffey, Hammer & Levi, 2011; Ford & Wargo, 2011; Nurkka, Viiri, Littleton, & Lehesvuori, 2014). The purpose of the discourse can set up a *rhythm of* *discourse* (Nurkka et al., 2014) where on some occasions the teacher plays an authoritative role as s/he directs the dialogue, and on other occasions students take the initiative to engage in conversation with each other as well as with the teacher by asking clarifying questions. Students are better able to think and discuss about a concept when they evaluate multiple explanations presented during classroom talk (Ford & Wargo, 2012). When argumentation was framed as a schema of *idea exchange* between teacher and students and between students, the conversations were fluid. "...Students were making claims, supporting claims with evidence and reasoning, attending to and challenging each other's claims and evidence, although they had had essentially no formal preparation in the skills of argumentation" (Berland & Hammer, 2012, p. 87), and activated their previous knowledge to construct new meanings.

Dialogic teaching is considered to support understanding because during conversations, students' connect their ideas with those of their peers and their teacher (Ford & Wargo, 2011). However, in order to participate in argumentation, the student has to know the content, which most students understand to a reasonable level. Additionally, students need skills of epistemic understanding to evaluate multiple responses to identify the one that best answers a question, which continues to be a challenge for many students. For example, Ford and Wargo (2011) in their research in a science class on Natural Selection found that students had *their own* understanding of the phenomenon, but in order to stay on task the teacher had to guide the conversation to ensure that students' understanding blended with the sanctioned scientific idea. In other words, the argumentation was not similar to the one that *true* scientific community engages in but emulated the apprentice-expert model with the expert (the teacher) guiding the apprentice (the student) in arriving at the answers. Thus, developing good argumentation skills is a cumulative process that requires scaffolding of learning (Berland & McNeill, 2010; Ford & Wargo, 2011; Freeman et al., 2014; Minstrell, Anderson, & Li, 2011).

Challenges of Argumentation in Science. Ford (2008, p. 416) does not advocate for "students to learn scientific knowledge in ways that parallel how scientists created it" but recommends, "scientific sense making" by students as they use science principles to *critique* ideas, instead of focusing only on *creating* knowledge. In order to argue, students need to understand the material, which requires a dialogic approach for scaffolding learning (Ford & Wargo, 2012) instead of explicitly learning argumentation as a skill. (Berland & Hammer, 2012; Ford 2008). However, teaching argumentation skills comes with its set of challenges that are worth considering.

Teachers may lack skills. Often when teachers pose questions to students the emphasis on initiation, response, and evaluation (IRE) of student answer, keeps the teachers' attention on comparing students' statements to expected response and rarely on students' substance of thought. Additionally, teachers may lack the skills to transition from a traditional IRE to a dialogic discourse. In their study of whole class discussions and interviews of five secondary science teachers Pimentel & McNeill (2014, p. 367) found that teachers "rarely asked probing questions or tossed back questions to the student." They framed questions that elicited "simple phrases or short sentence" (p. 367) responses. Additionally, teachers often cite "concerns about students' previous experience, knowledge, and motivation to participate in dialogic, extended science talk, as well as on their own ability to orchestrate this type of talk" (Pimentel & McNeill, 2014, p. 385) which raises the issue of professional development to facilitate argumentation. Teachers' insecurity about their ability to facilitate argumentation can be mitigated to a large extent if they focus on listening to students and providing feedback based on students' reasoning, and incrementally weave argumentation into their instruction. Ruiz-Primo and Furtak (2007) provide an epistemic and conceptual framework (ESRU) that teachers can adopt and/or adapt to engage learners in conversations in science classes.

Students may have grade sensitivity. A tension between grade sensitivity and desire for deep learning (Higgins, Hartley, & Skelton, 2002) and focus of teacher feedback on maximizing performance rather than on improving learning (Brown, Harris, & Harnett, 2012) in high stakes testing environments explains why despite their awareness of the value of argumentation, teachers continue to focus on information dissemination and adopt authoritative stance during discussions.

Cognitive load and confusion. Critics of the inquiry method (supported during argumentation) argue that minimally guided approaches where teacher stays in the background as students design investigations to answer questions, creates cognitive load (Kirschner, Sweller, & Clark, 2006) and leaves gaps in students' understanding of concepts which interferes with learning. There is concern that students may learn wrong information or may not be motivated to follow through with the assigned task (Scardamalia, 2002). Additionally, immersing students in authentic science activities, for example internships in research labs, does not lead to their understanding of the practice of science (Hsu, van Eijck, & Roth, 2010). Encouraging students to reflect on their experience, to make connections between their content knowledge and the work in the lab, and to evaluate multiple explanations, leads to increased ownership and immersion in the enterprise of science.

Argumentation is a complex learning practice and hence is not devoid of confusion and the accompanying effects of frustration and boredom, and cognitive load (D'Mello, Lehman, Pekrun, & Grasser, 2014). Figure 2 shows the emotional transitions a learner experiences during classroom discussion. When students are unable to resolve an academic argument it leads to a state of confusion then frustration and finally disengagement.

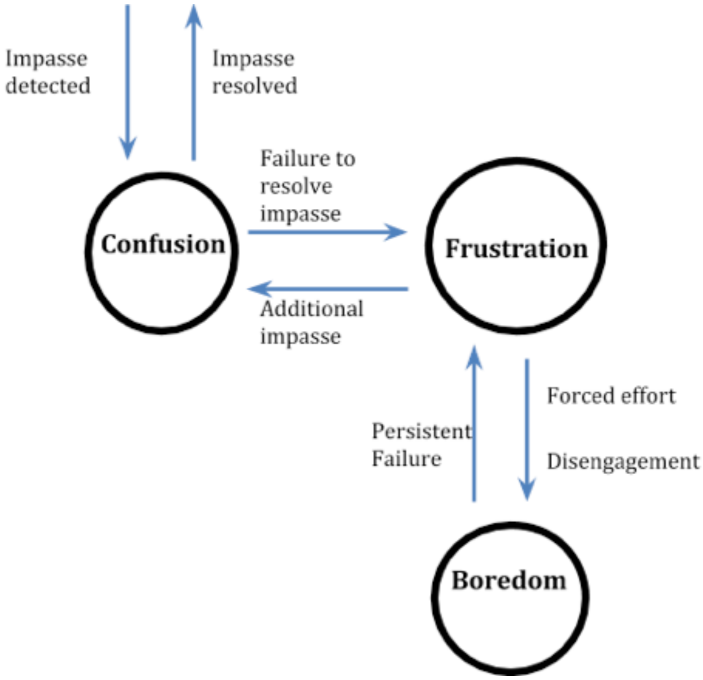

Figure 2. Observed Emotional Transition and Their Hypothesized Causes. Reprinted from "Confusion Can Be Beneficial to Learning" by S. D'Mello, B. Lehman, R. Pekrun, and A. Grasser, 2014, *Learning and Instruction, 29*, p. 161.

Finding the optimum balance between letting students persist as they revise their existing mental models to problem solve, and the teacher resolving conflicting explanations is essential to ensure productive learning. Although some level of confusion is helpful in student cognitive arousal and deep learning, if the discrepancy is not identified and corrected, the state of confusion can be counterproductive to learning.

The teacher's role in framing argumentation (Berland & Hammer, 2012; Ford & Wargo, 2010) is therefore vital to ensure progression in learning (Berland & McNeill, 2010), by aligning the conflict in students' understanding of the material with the goals of the lesson and the abilities of the learners. According to Vygotsky's (1986) Zone of Proximal Learning theory, learners can be challenged at the extremes of their zone of proximal development, and therefore confusion during learning can be tolerated, provided that scaffolds are in place that help learners to make sense of the material while when struggle. Additionally, if students can manage the challenges in their conceptual understanding of the material with self-regulated learning strategies, they are not demotivated during their state of confusion. (D'Mello, et al., 2014).

Norms of argumentation. Norms of arguments in class are different from norms of arguments in the real scientific community. First, the students generally direct their responses to the teacher instead of at each other. Second, although students may make multiple assertions and justifications during argumentation, they less frequently provide warrants, or generate counter arguments and rebuttals. In other words, students are comfortable justifying their position but less comfortable in challenging claims made by their peers. Thus they engage in argumentation without fully using it as a source of epistemic learning (Ford & Wargo, 2012; Llewellyn, 2013; Manz, 2014; Sandoval, 2004). Students' practical epistemologies or sense-making practices in science are much different from formal epistemological understanding of the Nature of Science (NoS) (Sandoval, 2004), and this difference can interfere with their productive use of argumentation or epistemic conversation to learning science.

In order to argue to learn, students have to first learn to argue. If they lack an understanding of their own learning processes, they have difficulty engaging in argumentation for learning. Fostering argumentation is challenging as students struggle with all aspects of it: proposing, supporting, critiquing, refining, justifying, and defending a position (Llewellyn, 2013). Teachers have to explicitly nurture through concrete experiences the skill of argumentation (Duschl, 2008; Ford, 2008; Minstrell, Anderson, & Li, 2011) in learners, which means that teachers need professional training to frame productive argumentation in their classes. Besides, epistemic practices do not transfer from expert settings to classroom settings without problems. Additionally, argumentation may not capture all the varied forms of learning within the discipline (Manz, 2014) and requires more in depth research as an effective tool to motivate students to study science.

Models for Analyzing Argumentation in Science Class

In analyzing science classroom discourses it is helpful to understand the difference between doing school and doing science. When the student is doing school he/she focuses on presentation of work to meet teacher expectation (Jiménez-Aleixandre, Rodríguez, & Duschl, 1999). In doing science the student consciously evaluates multiple claims and justifications in order to develop an understanding of underlying principles.

The nature of dialogue in a doing school context revolves around procedural issues, communicating information about expectations and deadlines, organization and display of information, teacher commendations and reprimands, and accepting knowledge as the basis for claims. The nature of dialogue in doing science shows the thinking that provides students' reasons to claims, rewording knowledge statements as it is applied within the context of the question, and evaluating contradictions in experimental data and theory. The interaction shapes the substance of the conversation rather than the goals dictating the conversation (Berland & Hammer, 2012; Heritage, 2010; Minstrell, Anderson, & Li, 2011). Argumentation in a science class covers both the mechanics of arguing which focuses on parts in an argument and the discipline specific content in an argument which helps to build understanding of the content being discussed.

Toulmin Argumentation Pattern (TAP). TAP looks at the mechanics of argumentation by dissecting an argument into its six parts: (a) Claims or thesis of an argument. (b) Data which is considered as providing evidence or reasoning for the claim (c) Warrants are assumptions or commonly held beliefs, and are specific to the discipline where argumentation is used (d) Backing which aims to bridge the gap between the author's warrants and the audience opinion (e) Rebuttals that present counter arguments after an invalid or wrong argument has been identified and (f) Qualifiers or words that quantify the argument, for example the use of words like most, few, or often provide conditions for the claim - which help to understand the strength of the argument. TAP is discipline independent, but what counts as a warrant, backing, or data is discipline specific.

Epistemic operators. To focus on the discipline specific aspects of argumentation in science Jiménez-Aleixandre, Rodríguez & Duschl (1999) developed epistemic operators (see Figure 3) that contextualize reasoning by supporting responses with evidence, drawing on prior knowledge, and by looking for patterns in constructing meaning. The epistemic operators strengthen the argumentation approaches identified by Toulmin's Argumentation Pattern (TAP)**.**

Epistemic Operator		***Description of Cognitive Reasoning***
Induction		Looking for patterns, regularities
Deduction		Identifying particular instances of rules, laws
Causality		Relation cause-effect, looking for mechanisms, prediction
Definition		Stating the meaning of a concept
Classifying		Grouping object, organisms, according to criteria
Appeal to	• analogy • exemplar/instance • attribute • authority	Appealing to analogies, instances or attributes as a means of explanation
Consistency	• with other knowledge • with experience • commitment to consistency • metaphysical (status object)	Factors of consistency, particular (with experience) and general (need for similar explanations)
Plausibility		Predication or evaluation of own/others' knowledge

Figure 3. Epistemic Operations for Scientific Reasoning. From "*Doing the lesson* or *doing science*: Argument in high school genetics," by M. P. Jiménez-Aleixandre, A. B. Rodríguez, & R. A. Duschl, 1999, *Science Education,* 84(6) p. 771. Copyright © John Wiley & Sons, Inc. Reprinted with permission.

Role of rebuttals. Analyzing epistemic content of conversation in science classes was developed further through the work of Erduran, Simon, and Osborne (2004) who analyzed only rebuttals because they found distinguishing clearly between warrants and data, and between warrants and backing in student conversation as problematic. Erduran, et al., (2004) argue that conversations without rebuttal rarely lead to a change in thought and ideas, and that rebuttals are essential for higher order thinking (see Figure 4).

Level 1	Argumentation consists of arguments that are a simple claim versus a counter claim or a claim versus a claim.
Level 2	Argumentation has arguments consisting of a claim versus a claim with either data, warrants or backing, but do not contain rebuttals.
Level 3	Argumentation has arguments with a series of claims or counter-claims with either data, warrants or backings with the occasional weak rebuttal.
Level 4	Argumentation shows arguments with a claim with a clearly identifiable rebuttal. Such an argument may have several claims and counter-claims.
Level 5	Argumentation displays an extended argument with more than one rebuttal

Figure 4. Levels of Arguments. From “TAPping into argumentation: Developments in the application of Toulmin’s Argumentation Pattern for studying science discourse,” by S. Erduran, S. Simon, & J. Osborne, 2004, *Science Education,* 88(6), p. 930. Reprinted with permission.

Whole class discourse. In addition to focusing on segments of classroom discourse that qualify as argumentation, researchers have also analyzed the entire discourse in the classroom to understand the weightage of argumentation within the multiplicity of classroom learning contexts. The Initiate-Respond-Evaluate model (IRE), (Mehal 1979) as a teacher guided authoritative mode of dialogue in the classroom has been used with some variations, by many researchers. One of these variations is the IRFRFRE and

IRFRFRF chains of interactions to categorize classroom interactions as teacher-guided dialogic discussions used by Nurkka, Viiri, Littleton, & Lehesvuori (2014), to understand how these lead to cumulative development of ideas in a physics class.

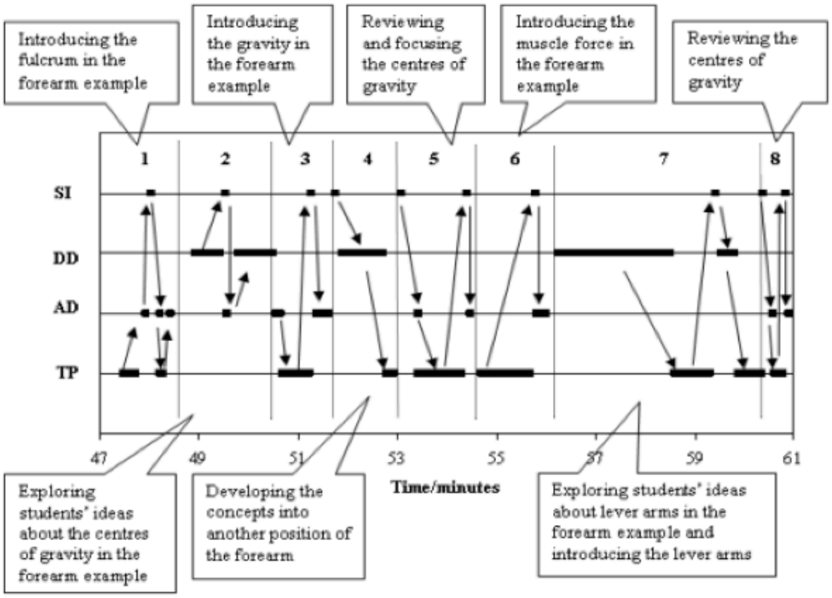

Figure 5. Classroom Discourse Map. From "A methodological approach to exploring the rhythm of classroom discourse in a cumulative frame in science teaching," by N. Nurkka, J. Viiri, K. Littleton, & S. Lehesvuori, 2014. *Learning, Culture, and Social Interaction, 3*, p. 59. Reprinted with permission
TP = teacher presentation, AD = teacher guided authoritative discussion, DD = teacher guided dialogic discussion, SI = student's initiative.

An example of the rhythm of conversation analyzed by Nurkka, Viiri, Littleton, & Lehesvuori (2014), within a science classroom is presented above (see Figure 5). The diagram shows that student initiated questions are often followed by the teacher guided authoritative comment, indicating teacher's control towards the goal of the lesson. Nurkka et al., (2014) included within the chain of conversation another variation called student initiation (SI) – questions or comments from students that can initiate dialogue.

Another model developed by Ford & Wargo (2012) adopts the ideological dialogue scaffolding variation (Modeling for Understanding in Science Education – MUSE) where the teacher retains the control as s/he guides and directs students through a series of questions to arrive at the correct response from multiple ideas. Students are engaged in a dialogue as the teacher scaffolds their understanding of concepts. Teacher directed dialogue is therefore considered helpful in facilitating understanding of concepts in a science class.

Although there are models that focus on the entire conversation chain to understand the rhythm and flow of dialogue, and others that focus on segments of argumentation, the language of science is important in science class conversations. Additionally, epistemic learning is cumulative as students develop over time the skills to evaluate rival explanations (Manz, 2004; Sandoval, 2004). Creating awareness in students and teachers of the value of dialogue to science learning is important for students' meaningful engagement in argumentation. Using TAP to analyze the structure of the argument and epistemic operations to analyze the nature of warrants, backing, and data, will help to understand causal mechanisms in science claims.

Motivation

Motivation is defined in social cognitive theory as "an internal state that arouses, directs, and sustains goal directed behavior." (Bryan, Glynn, & Kittleson, 2011, p. 1050). Although motives don't have a direct impact on achievement, "when explicit goals and implicit motives are congruent" then individuals perform better (Pintrich, 2003, p. 670).

Six constructs – self-efficacy, locus of control, and attribution, which determines the learner's perception about their ability to complete a task; goal orientation and intrinsic vs extrinsic drive that impact learner's purpose for engaging in a task; and self-regulation, which refers to strategies that the learner uses to complete a task - are helpful in explaining the traits of motivation, which I elaborate further in the following paragraphs.

Learner perception to complete a task. Learners' perception about their ability to complete a task is founded in their incremental success in tasks of appropriate level of challenge. Self-efficacy in Bandura's (1993) social cognitive learning theory represents individual's perception to control the outcome of a task through actions influenced by observations, thoughts, emotions, and collaborative work with others (Schunk, 1995). Students who believe that they are capable for performing certain tasks develop metacognitive strategies and persist harder to complete a task (Zimmerman 2000). Thus their locus of control is internal and they take personal responsibility (personal attribution) for outcomes. When students with high self-efficacy were confronted with challenging tasks they attempted different strategies or developed new approaches to complete the task (Bandura, 1993). Vygotsky's zone of proximal learning underscores the value of scaffolding learning by taking learners from simple to complex tasks as well as by providing them with opportunities to learn with and from others, in order to develop new skills and new material.

Positive feedback can enhance intrinsic motivation but when feedback is administered to promote learner autonomy then motivation is sustained and internalized

(Brooks & Young, 2011). Additionally, students who set proximal goals rather than distal goals tend to experience high levels of self-efficacy and learning growth, as attainment of proximal goals provides evidence of achievement (Bandura, 1985; Pintrich, 2003, Zimmerman, 2000). Although learner autonomy is a precursor to self-regulation it is helpful for teachers to provide a framework where engagement between learners does not disrupt the flow of learning.

Learner's purpose to engage in a task. Learners bring in different needs, skills, passions, personal experiences, and purposes, which drive their motivation to learn. The continuum of learners - from those who respond well to outside recognition and rewards (performance goals) to those who work to satiate their cognitive appetites (learning goals), as well as those who possess both performance and learning goals simultaneously (Pintrich & Garcia, 1991) - creates opportunities and challenges for the teaching-learning dynamic. Additionally, learning is not a monotonous experience even for an individual learner over time or across various academic disciplines and life contexts. Although the purpose of engaging in a task is fluid, purpose can be intrinsically or extrinsically informed, but it drives motivation to learn.

Learner's strategies to complete a task. Self-regulation is a trait of motivation identified as "a process through which self-generated thoughts, emotions, and actions are planned and adapted to reach personal goals" (Zimmerman, as cited in Panadero, Alonso-Tapia, & Reche, 2013, p. 1) and a predictor of academic success. When the learner carefully evaluates academic strategies that worked or did not work for successful completion of task, s/he is able to choose from a range of possible alternatives one that will work best in a new context. Adapting strategies to the task goal is a skill developed by learners with a high sense of agency (Zimmerman, 2000). Learners draw on the resources available to them, especially their peers and their teachers, to maximize their educative experience; thus self-monitoring, self-reflecting, and self-evaluating for self-improvement. Some studies (Deci, Vallerand, Pelletier, & Ryan, 1991) indicate that when learners are denied the interpersonal involvement they desire, they can lose intrinsic motivation. Hence, in addition to providing contexts that enhance motivation instructors must be careful to avoid creating situations that can suppress motivation.

The interaction between the learner, the instructor, the material being learned, and the environment or context of learning have a bearing on developing self-actualized, autonomous learners. Two theories of motivation - Maslow's Hierarchy of Needs theory and John Keller's Attention, Relevance, Confidence, and Satisfaction (ARCS) model - provide insight into how instructors can design lessons to motivate learners. Maslow's model proposes that individuals work to meet higher order (growth) needs of self-actualization only when their lower order (deficiency) needs of safety, belongingness, and self-esteem are met. Keller's (2010) ARCS model of motivational design refers to instructional strategy and principles that engage the learner by providing optimal challenge and support, vital for building confidence and motivation for sustained learning. The instructional implications of both the theories of motivation is that keeping the characteristics and interests of learners, the dynamics of social interactions, and the use of multiple resources that engage different learners; is vital for deep learning. Additionally, to be effective the motivation tactics must support instructional goals.

Theoretical Framework: Social Cognitive Theory

Human capacity can range from being agentic, curious, creative, keen to learn, and able to grow their talents; to being alienated, discouraged, disinterested, indolent, and rejecting growth and responsibility. Although individual predisposition has some effect on human motivation and behavior, social contexts can catalyze individual's development and well-being. Learning happens within a social context and much of what is learned is influenced by experience and observation. The three assumptions of social-cognitive theory that are not mutually exclusive and the ones that relate well with my research on argumentation and motivation are, triadic reciprocality, human agency to control behavior, and that learning may not produce immediate behavior.

Triadic Reciprocality

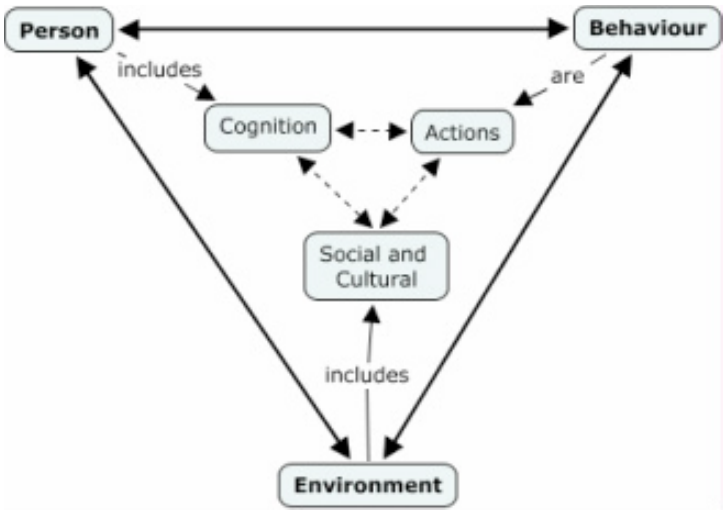

Figure 6: Triadic Reciprocity
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Learning is an outcome of the triadic reciprocity (bidirectional reciprocal interaction) of personal (cognitive, metacognitive, emotional, and physical traits), behavioral (self-observation, self-evaluation, engaging in class, taking responsibility), and environmental (contextual – nature of task, social & physical environment, reinforcement, modeling) factors (see Figure 6). Individual choices (behavior) are determined by the stimuli provided by the environment and by internalization of previous experiences of levels of success.

Outcomes of actions have a direct bearing on the environment and on individual self-concept. However, as a member of a socio-cultural context (environment) the individual both conforms to and informs its norms and practices. Thoughts have a functional value particularly as individuals evaluate the effects of their actions and make further changes in their thoughts and action to complete tasks, and to take on progressively challenging tasks. Self-efficacy or belief in one's ability of meeting a goal is one outcome of triadic reciprocity.

Self-efficacy. While external stimuli trigger actions and responses, over time individuals develop an awareness that their actions have an impact on their environment and hence on their experiences. When individuals believe that they can produce desired effects by their action (self-efficacy), they have incentive to act, they persevere, and they are able to develop self-regulation in order to set goals, pace themselves to complete tasks, and to take on progressively challenging tasks. Factors influencing self-efficacy include:

Mastery experience. Mastery experience instills a strong sense of self-efficacy in people, particularly in students. Success on easy tasks leads to an expectation of immediate results and discouragement from failure. However, overcoming obstacles through support and guidance, which leads to self-improvement and which consequently leads to perseverant effort builds students' resilience and self-efficacy.

Social persuasion. Encouragement promotes self-efficacy while discouragement decreases self-efficacy. This is particularly true in peer-to-peer interactions and therefore it is important that training to engage in argumentation involves mutual respect, others' perspective taking, and skills of civil disagreement. Although students are less aware of their emotions during learning, creating learning situations where students feel safe reduces their anxiety and builds their capacity to engage in learning, especially their ability to take on challenging and difficult learning stimuli.

Vicarious learning. Vicarious learning or learning by observation of others or of a model is central to socio cognitive theory. The student is motivated to attempt a task based on his observation of success experienced by others on the task. While success may not be achieved at the first attempt, seeing others struggle before eventually succeeding gives individuals confidence in persisting towards their goals. For example, a student who is shy and reluctant (personal trait) to participate voluntarily in class, may, as a result of his/her observation and assessment of the teacher's encouragement of other students (environmental factor), take the risk of volunteering (behavior) his/her answer.

Modeling and observations convey rules of generative behavior that the learner can use to successfully attempt tasks. Learning from observation is not about mimicking others' behavior but opens up multiplicity of actions where the learner can make judgments about why things worked and how to adapt learning to new situations. Additionally, observation or evaluation of their own performance makes it possible for learners to transfer learning from one context to another. Learners who persevere develop a high sense of self-efficacy and are able to achieve incrementally challenging goals.

Human Agency

In Social Cognitive theory acquisition of knowledge is an outcome of the agentic (intentional) effort of the learner, who sets personal goals, takes ownership of the goals, and works to achieve the goals. Additionally, personal agency operates within the framework of socio structural influences. Social systems have "rules, resources, and social sanctions designed to organize, guide, and regulate human behavior…and these systems are created, implemented, and altered by human activity." (Bandura, 2004, p. 76).

Pimentel & McNeill (2010) compared three classes where students received similar instruction regarding argumentation. They found that when teacher asked open-ended questions students engaged with each other's ideas in a substantive manner, indicating that the context of learning, and more specifically how the student experiences the context of learning, has an impact on students' engagement with learning. In another study on framing of argumentation – how teachers and students experience/interpret what is going on in class - Berland & Hammer (2011) compared three different classroom conversations. They found that the class where the teacher retained an authoritative epistemic and social stance, discussions were discordant, and where teacher maintained control but allowed for open discussion, the conversation was argumentative (organic) as students tried to reason their position and win their classmates over to their side, but when an external reward (for example: recognition from teacher) was a motivator class discussions were contrived and less robust.

To summarize, in order to engage learners and to build the agency of the learner, the instructor has to design instruction so that the learner actively partakes in the process of learning, and model learning activities that students can adopt during initial phases of learning and adapt as their academic competencies progress.

Collective agency. Social cognitive theory extends the concept of human agency to collective agency as individuals operate within a social context (Bandura, 2001). Collective agency is sustained through dialogue as a primary mode of communication. The dialogic approach or the pedagogy of argumentation allows each individual to develop his/her unique path to mental models and to arrive at a common understanding of knowledge. For example, the affirmation the student experiences both from peers and the teacher (interaction between behavior and environment), may lead to more thoughtful input from him/her that could possibly improve the learning dynamic for the classroom. Furthermore, the student is able to transfer (agentic effort) the successful experience from one class to explore stepping out of his/her comfort zone in another class; thus leading to his/her ability to modify the learning experience – individual and collective.

Self-regulation and motivation. Bandura (1991) states, "In social cognitive theory human behavior is extensively motivated and regulated by the ongoing exercise of self-regulation." (p. 248). Social contexts that support individual's competence, relatedness, and autonomy, promote intentional (i.e. motivated) action (Deci et al., 1991). Action. According to self-determination theory, autonomy implies that individuals perceive that they can exercise choice in their actions, which are self-controlled and self-regulated; competence refers to the ability to complete tasks to universally and socially accepted standards of performance; and finally, in order to feel safe in exercising choice and working towards incrementally challenging goals, individuals must feel a sense of inclusion and relatedness within the community, including a connection with the teacher.

Instruction that supports learner autonomy and competence is more likely to sustain learner curiosity and more likely to develop self-regulation in learners through internalization and integration (Brooks & Young, 2011). Additionally, learning experiences that enhance students' self-worth have a direct impact on their affect to participate in learning (Pintrich 2003) and develop self-regulation strategies to successfully attain learning outcomes despite challenges (Zimmerman, 2000). Negative affect (for example fear of failure) can lead to more careful processing of information and therefore can occasionally be good (Pintrich, 2003). Although Self Determination theory is a theory of motivation, I will devote a section towards the end on motivation, as it is the dependent variable in the quantitative part of my study.

Learning can Occur Without Immediate Change in Behavior

A demonstration of what is learned need not immediately follow learning. As discussed under vicarious learning, observation of others' behavior and experiences can lead to self-reflection and internalization of learning. The learner develops cognitive constructs (rules, values, skill assessment) that can inform behavior at a later stage when motivated to act. Additionally, the learner can set goals and select cognitive processes and behavior (self-regulate) to achieve the goals.

Constructing knowledge. Constructivist paradigm arises from socio-cognitive theory of learning and posits that learning is an active, constructive process. The learner, through observations, personal reflection, and through dialogic participation with others, actively constructs knowledge. The engagement of the affective and the cognitive dimensions is instrumental in sustaining interest and meeting the needs of the learner. Hence, instructional design where the learner's curiosity is ignited, and which requires the learner to draw on his/her prior knowledge and skills to make sense of new information, to reflect within the group context, and to communicate, represent, and argue his/her justification initiates a process of negotiation and evaluation (Ruiz-Primo & Furtak, 2007). This makes learning participatory, meaningful, relevant and purposeful for the learner.

In social cognitive theory, "people are agentic operators in their life course who use their sensory, motor, and cerebral systems as tools to accomplish the tasks and goals that give meaning to their lives…The human mind is generative, creative, proactive, and self-reflective not just reactive" (Bandura, 1999, p. 5). Learning that emerges through observation or modeling, followed by guided practice and dialogue develops competencies that generate a perception of self-efficacy or belief in one's ability to exercise control over events to accomplish desired goals. These self-beliefs influence the choices individuals make to follow a course of action, their resilience, and whether their thought processes are self-hindering or self-aiding (Bandura, 1988). This in turn has an effect on their motivation and the effort they will put in a task.

Social Cognition and Argumentation in Science Class

The dialogue in classes whether it happens within the context of a hands-on activity or during instruction has been given different labels by researchers – classroom talk (Pimentel & McNeill, 2013), disciplinary substance of conversation (Coffey, Hammer, Levin, and Grant, 2011), explanation driven inquiry, assessment conversation (Ruiz-Primo & Furtak, 2007) and argumentation (Erduran, Simon, & Osborne, 2004; Berland & Hammer 2012) – and they are all guided by the objective to give students an opportunity to engage in authentic learning experiences in science. According to Ford and Wargo (2012, p.3) "...the act of explaining is dialogic because it involves picking up another person's utterance—that is, the scientific idea—from its time, context, and purpose, and using it in one's own situation, to advance one's own feeling of understanding."

Although argumentation is nascent to all individuals, social and cognitive contexts cause individuals to monitor what they say, how they say, and to whom they respond. Students tend to vest authority of knowledge in the teacher and therefore rarely contest information imparted by their teacher. Consequently, students tend to memorize facts in science, develop a tentative understanding of information, and hold on to misconceptions in the absence of an opportunity to address or rectify these misconceptions (Ford & Wargo, 2012). Additionally, during a discussion students tend to rally behind ideas and explanations presented by their peers (Kelly, Druker, & Chen, 1998; Kuhn & Udell, 2007) that agree with their own, or stay quiet if they disagree. However, Manz (2014) found that in classes where argumentation is driven by intrinsic desire to participate, conversations are robust and students are willing to challenge disagreements with their thoughts (not rally behind similar thoughts). Hence, scientific reasoning or domain specific argumentation requires attention in the teaching-learning practice, particularly with reference to the socialization of the learner within the context of the classroom.

The theory of social constructivism in science education (Duit & Treagust, 2003) advances the value of dialogue and active classroom participation for the learner as a precursor to student motivation. Scardamalia (2002) advocates a knowledge building pedagogy "to engage students in the collaborative solution of knowledge problems, in such a way that the responsibility for success of the effort is shared by the students and the teacher, instead of being borne by the teacher alone." (p. 8). Through the use of Computer-Supported Intentional Learning Environments (CSILE) she presents examples for *learning with understanding* where every learner had an opportunity to express, justify, clarify, build-on ideas that lead to collective learning within the group. Instead of imparting knowledge, the teacher creates an environment for students to construct knowledge from the tasks they engage in. Model-centered learning, in addition to empowering learners to construct knowledge for understanding, underscores the epistemic value of creating situations for student reflection and evaluation of their thought processes (thinking and reasoning), since the process is active and evolves as the individual "comes in contact with new ideas and concepts, listening to lectures, experimenting with new ideas, and sharing thoughts with others. (Savard, 2014). However, both teachers and learners have to be comfortable with ambiguity, and students in particular have to be willing for their learning to evolve as different models arising from different ways of thinking about the idea emerge.

Focusing only on the social context of the interaction, particularly the shift from transmission approach to dialogic approach is not the answer to getting students engaged in studying science. In fact, even if the teacher uses a didactic approach but integrates questions with the objective of scaffolding understanding of science concepts, the gain in learning for students is tremendous (Ford & Wargo, 2011; Iordonou, 2010). Similarly, engaging students in lab activities does not necessarily translate into their understanding of the material. Requiring students to reflect and to discuss their findings helps them understand the material and to engage in the enterprise of science.

If students are to develop scientific ways of knowing then it is important that feedback "helps learners to move from what they already know to what they are able to do next, using their zone of proximal development" (Shepard, 2005, p. 66) and provides opportunities for critical perspective to become aware of how claims are made in scientific knowledge. Additionally, conversations within the class make instructors aware of prior knowledge (and misconceptions) students bring to class. When the instructor refines instruction, informed by incorporating his/her understanding of the thought process of the learner, it eventually leads to increased competence towards learning goals for the learner.

As the instructor engages in a conversation with one student, many more learn from the exchange. (Schraw, Crippen, & Hartley, 2006). In vicarious learning, an individual learns by observing others perform a skill or discuss a topic. The anxiety level for the learner is low and they focus their energy on understanding ideas as these unfold. Creating conditions for spontaneous argumentation will allow students to engage in the process of mutually building knowledge instead of working to meet teacher expectations. Additionally, the focus will shift from *form and method* of arguments to the content essential for arriving at answers. This means that when science teachers intentionally integrate evidence and science principles in their explanations then students learn to focus on evidence and concepts during their responses. Thus students will be engaged in the practice of science as they get comfortable justifying and evaluating their own and their peers' responses. According to the National Research Council (2012), the explanation provided during argumentation provides evidence of students' understanding. Additionally, supporting their reasoning with evidence validates the nature of science dependent and emergent from evidence based dialogue.

Summary

In chapter 2, I made an attempt to understand argumentation within the learner's context by discussing the conceptual framework of argumentation (for the qualitative question) and the social cognitive theory of learning (for the quantitative part of the study). A brief discussion on motivation to learn is embedded between the conceptual and theoretical frameworks. Motivation discussed the three characteristics that engage learner – perception to complete a task, purpose to engage in a task, and strategies to complete the task – as s/he asks the questions of what, why, and how to learn. I tied the frameworks to my literature to help guide my study towards its purpose and significance. In the final section on social cognition and argumentation I argued that engaging all students in productive classroom talk can be empowering for the learner and can lead to intrinsic motivation to learn. Creating a climate of mutual respect helps to build confidence in students to express and defend their opinions, work collaboratively, and to ask clarifying questions of their classmates. Additionally, listening to their classmates' reasoning makes strategies that successful students use visible and accessible for the timid learner. Furthermore, social interaction and language are central to developing knowledge and understanding in science (Nurkka, Viiri, Littleton, & Lehesvuori, 2014).

In chapter 3, I examine the research methods of this mixed methods concurrent nested design. I describe my role as a researcher in the private K-12 school in Delhi, India. I identify the process of selecting and contacting participants. The qualitative research question studied how teachers planned and facilitated argumentation in class and the quantitative question undertook statistical analysis of student responses on SMTSL instrument. Data analysis plan is described in detail. Issues of trustworthiness, transferability, and ethical procedures conclude the chapter.

Chapter 3: Research Method

The purposes of the mixed methods concurrent nested study were to understand how science teachers planned for and facilitated argumentation and to explore whether student motivation in science classes changed as a consequence. While some science classes use argumentation as a pedagogical approach, its widespread application requires an understanding of how it is used well in classrooms so that skills to integrate argumentation within the plurality of instructional practices in science classes can be developed through professional training (Berland & McNeill, 2010; Ford & Wargo, 2012; Pimentel & McNeill, 2013). Just as the zone of proximal learning is appealed to enhance student learning, similarly, examples of teacher directed argumentation can guide the teaching community to develop comfort and skills with providing space for students to challenge ideas and to take ownership of learning through self-regulated action. My study looks at one context where a few science teachers stepped outside their zone of professional comfort and experimented with argumentation in the science class.

In Chapter 3, I examine the research methods of this study. Specifically, I have described my role as a researcher within the K-12 school and identified the procedures used to obtain participants. The qualitative research questions are designed to understand how teachers plan for and facilitate argumentation in their classes while the quantitative question uses students' self reported perception on the SMTSL instrument to explore changes in student motivation as a result of learning in a science classroom that uses argumentation approaches (Tuan, Chi-Chin, & Shyang-Horng, 2005). The methodology section includes participation selection logic, instrumentation of researcher-developed interview questions, discussion of a valid quantitative survey instrument developed by Tuan, Chi-Chin, and Shyang-Horng (2005) and subsequently used in multiple studies, recruitment for this study, participation and data collection procedures, and data analysis plan. Issues of validity of quantitative data and trustworthiness of qualitative data, as well as ethical procedures for conducting research, conclude this chapter before a summary.

Setting

My study took place in a K-12 private school in Delhi, India. The school has an enrollment of approximately 1,000 students. Its science department has eight science teachers. This study collected data only from the four teachers who taught ninth grade science. Although the school is affiliated with the Central Board of Secondary Education (CBSE), which provides a framework for the academic program, the school exercises flexibility to design a curriculum up to Grade 8 that best meets the needs of its students while at the same time maintaining a competitive program among its peer schools. Two national level examinations, at the end of Grades 10 and 12, are mandatory for all students (CBSE Examination Bylaws, 2013)

The education department in India mandates that all high school teachers earn a degree in education in addition to an advanced degree in the discipline that they teach (CBSE Affiliation bylaws, 2012). The teachers who participated in my study have a master’s degree in either physics, chemistry, or biology. They also have a bachelor’s degree in education. This level of teachers’ educational qualification was the primary motivator for me to base my study at the school. I believe that the participating teachers’ academic backgrounds provide them with the content knowledge to engage students in deep conversations about subject matter. I also believe that their training in educational pedagogy, particularly in science education, gives them an understanding of curriculum and pedagogy in science. This study gave me an insight into seeing how teachers facilitated argumentation and used student responses to guide classroom discourse.

Additionally, the range of students' academic interests and socioeconomic status provided a spectrum of student motivation to learn. As over 90% (S. Kumar, personal communication, December 2013) of the student body started studying at the school from elementary classes, they had a similar content background of science. Furthermore, the vertically coordinated science curriculum and the accountability system at the school created an environment conducive for science teachers to work in collaborative teams. The fact that the teachers in the science department worked collegially (S. Kumar, personal communication, December 2013), to ensure continuity within the science curriculum that minimized gaps in instruction, was an additional factor that drew me to the school for my study.

Ninth grade followed an integrated science curriculum with instruction time devoted each to biology, chemistry, and physics each week. Hence, students in the class studied three different topics (biology, chemistry, and physics) concurrently. Additionally, because the ninth grade class was taught by two teachers, one of whom had a degree in biological sciences while the other had a degree in the physical sciences, each ninth grade student learned from two science teachers throughout the year. This arrangement of two teachers sharing instruction time in class necessitated coordination between teachers to ensure syllabus coverage and to address student needs. Add concluding sentence.

Research Design and Rationale

The guiding research question for my study is, How does the use of argumentation in science instruction motivate students in science classes? The research question encompasses two major concepts: argumentation and motivation. Witnessing classroom instructions will help me understand, describe, and expand knowledge about what teachers do in their classrooms to engage students in argumentation. Speaking with teachers will provide me with a perspective on how teachers plan to facilitate argumentation. Motivation will be measured and statistically analyzed from students' responses on the Student Motivation Towards Science Learning instrument. While argumentation will be analyzed using qualitative methods, inferential statistical techniques will be used to determine if argumentation leads to significant changes in students' motivation in science class. Therefore, neither qualitative nor quantitative method solely answers the research question, and a mixed methods approach emerged as most suited for the study. The mixed method approach allowed me to focus on different questions for the qualitative and the quantitative components and afforded a holistic understanding of the use of argumentation and its perceived benefits. Education literature (Berland & McNeill, 2010; Coffey et al., 2011; Cinar & Bayraktar, 2014; Iordanou, 2010; Kuhn, 2010; Osborne, 2010) has analyzed argumentation from the perspective of teachers' instructional practices but integrating student perception of changes in student motivation as a consequence of participation in argumentation is hypothesized to increase the robustness of my study.

The research question was therefore divided into three subquestions. The qualitative questions included

1. How do teachers plan to incorporate argumentation in their instruction?
2. How does argumentation occur in the classroom in terms of epistemic operators?

The quantitative question included

To what extent does the student motivation in the science class change after students engage in argumentation in class?

Null Hypothesis (H_o): There is no change in student motivation before and after they engage in argumentation in class.

Alternative Hypothesis (H_a): There is a change in student motivation in the science class after argumentation has been introduced to classroom instruction.

Choice of mixed methods strategy. My mixed method design is a concurrent nested approach with the quantitative study embedded in the qualitative study (see Biddix, 2009; Creswell, Plano, Guttmann, & Hanson, 2003). This means that while understanding how teachers plan for and facilitate argumentation in their science class is the primary focus of my study, I am also interested in exploring whether students' experience with argumentation led to a change in their motivation in the science class. The analysis of student motivation data, however, only helps to develop a richer insight into argumentation in the science class. I selected the concurrent nested design because this integrated approach allowed me to understand argumentation from two different perspectives--students and teachers--which “stimulate(s) a creative tension in the study.” (Cronhlom & Hjalmarsson, 2011, p. 88) as I attempted to connect qualitative data on planning and implementation of argumentation in class with quantitative analysis based on student responses. Students provided quantitative data while teacher practices provided qualitative data. The objective was not to triangulate findings from the two sets of data and therefore the sequential mixed methods approach to data collection was ruled out.

My research question investigated the practice of argumentation during instruction and consequent changes in student motivation. The process of planning for and integrating argumentation in the classroom was the focus of the qualitative data. Inferential statistical analysis of student responses on the SMTSL instrument, with gender and student performance as covariates, was the focus of quantitative data collection and analysis. However, since the quantitative data was not based on probability sampling, and since qualitative data used convenience sampling, qualitative data is weighted more than quantitative data in my study. In sum, the primary aim of the study was to understand argumentation and the secondary goal was to study its effect on student motivation, which explain why quantitative component of the study is nested in the qualitative component of the study.

The model drawn below (Figure 7) best describes my mixed methods approach. The qualitative part of the research entails data collection from (a) one-on-one interviews with each of the four ninth grade science teachers to understand how they planned to implement argumentation as a pedagogic approach in their class and (b) classroom observation of each grade nine science class as teachers delivered instruction. I took detailed notes of instruction and conversation during class. Student responses on the Student Motivation Towards Science Learning instrument provided quantitative data for the study. Quantitative data is secondary data as it was collected, de-identified, and combined pre– and post– engagement in argumentation in their science courses, by the school and provided to me for analysis. In order to accommodate my study, the school coordinated collection of student responses on the SMTSL instrument immediately following the one-on-one interview with the ninth grade science teachers for pre–intervention data and immediately following the week of class observation for post-intervention data.

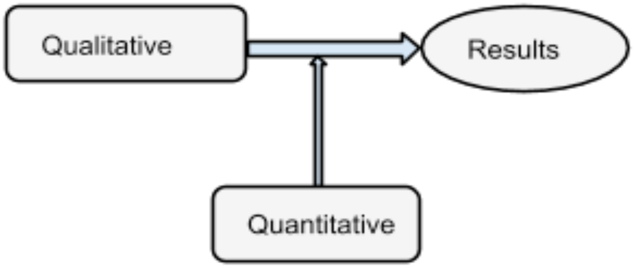


Figure 7. Diagrammatic representation of the mixed methods study

The research was conducted in a single phase. Following the recommendation from Creswell, Plano, Guttmann, and Hanson (2003), I considered timing, weighting, and mixing of data in developing my design. In terms of timing, qualitative data from teacher interviews was needed to assess how teachers planned to facilitate argumentation in their classes. Taking thorough notes while observing teachers' facilitation of argumentation during instruction helped to understand how teachers integrated argumentation into their lessons. Quantitative data was collected before and after teachers implemented the pedagogy of argumentation. The two data sets – qualitative and quantitative – are independent of each other and collected concurrently.

Qualitative and quantitative data were analyzed separately but were brought together during the discussion (interpretation) phase. Quantitative data supplements qualitative data to expand and complement my understanding of argumentation in a science class. The results from both qualitative and quantitative analysis will inform teachers and students of the needs and/or practices of each other.

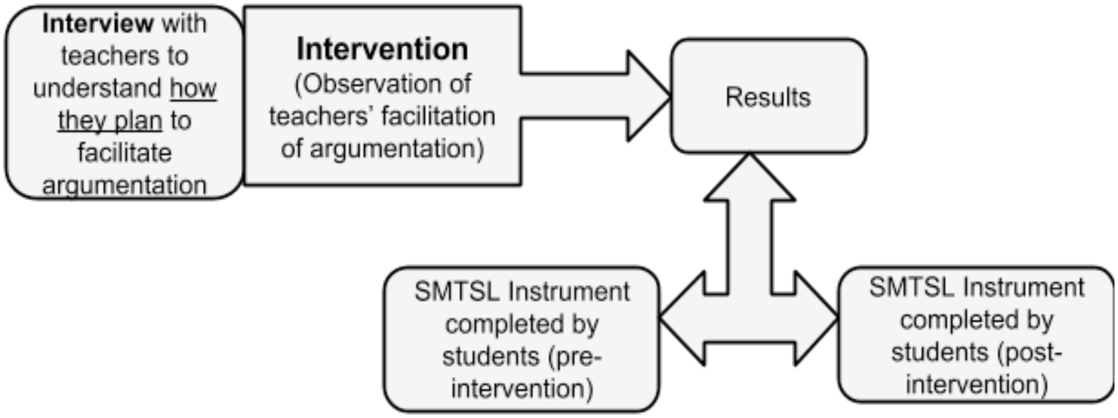


Figure 8. Concurrent qualitative and quantitative data collection plan.

The combination of qualitative data provided by teachers and quantitative data provided by students (see Figure 8) helped to develop a deep understanding of argumentation in a science class. Making connections between qualitative data based on pedagogical approaches teachers believed would improve student attitude towards science and quantitative data provided by students about their perception of their motivation in the science class collated perspective from two stakeholders and helped to evaluate whether argumentation was indeed valuable for all students in the science classroom. The mixed method approach is helpful in monitoring changes over time and in the process of framing policy (Ivankova, 2014, p. 65).

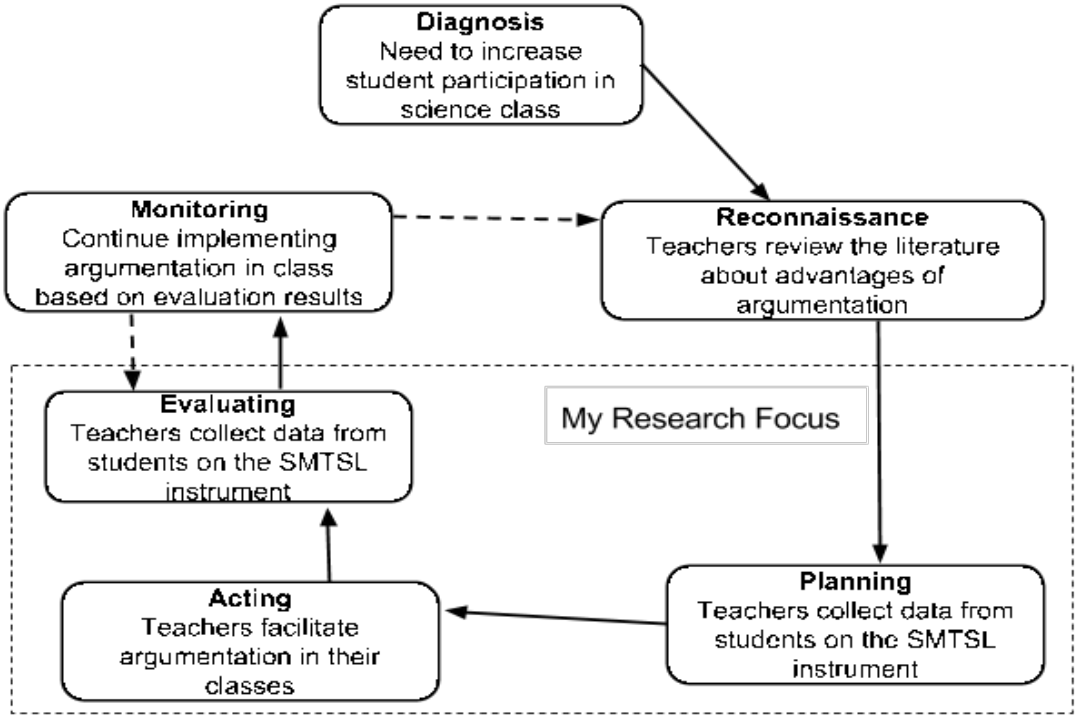


Figure 9. The mixed method research focus of the study within the MMAR.

The design of this study emulated the schematic of Mixed Methods Action Research (MMAR) where the teachers were engaged in identifying the need for integrating argumentation in their instruction to increase student participation and evaluating its impact on learning (Kostos & Shin, 2010). Teachers read relevant literature about the value of argumentation and came up with their plan to facilitate argumentation. The teachers collected data to evaluate their approaches and to monitor the impact of argumentation on student motivation. Although the teachers at the school were undertaking a self-study the school granted me permission to interview teachers and to observe (and take notes) their classes for the week they facilitated argumentation. Within the MMAR framework my mixed method research covers the planning, implementation, and evaluation (of impact of argumentation on student motivation in science class) phases.

Hence the scope of my research is limited to and defined by the collection of qualitative data from one-on-one teacher interviews to understand how they planned to facilitate argumentation and from classroom observation of instruction that uses argumentation, analysis of qualitative data, and analysis of de-identified quantitative data (see Figure 9) provided by the school. De-identified data from students' response to the SMTSL questionnaire is secondary data as it is collected by the school and shared with me. In order to accommodate my study, the school collected student responses (pre and post intervention) to the SMTSL instrument immediately following the one-on-one interview with the teachers and immediately following the week of classroom observation (post-intervention). Quantitative data was combined for pre and post argumentation based instruction in class. I shared my analysis of classroom observation data with teachers via Skype and informed them that they could request to see the analysis of quantitative data if needed.

Role of Researcher

As a researcher I came into the self-study the ninth grade science teachers had decided to undertake at the K-12 school. While the science department had identified the need for engaging students in argumentation with a goal to increase their participation (and therefore their motivation) in science, I interviewed teachers to understand their plan to facilitate argumentation, observed classroom discourse as teachers used the pedagogy of argumentation, and analyzed secondary data provided by the school about students' self-reported perception of changes in their motivation in the science class as a consequence of engaging in argumentation.

I was the primary instrument in collecting qualitative data. Before the start of the study I shared my curriculum vitae and explained the purpose and nature of my study to the principal, the science department, and the participating teachers. I familiarized myself with the routines of the school particularly the science department in order to minimize the effect of my presence during data collection.

Qualitative data collection started with interviewing teachers to understand how they planned to facilitate argumentation in their lessons. Following my meeting with teachers I sat through their lessons, took detailed notes of classroom discourse, and analyzed (quantify) the conversations for rhythm of discourse (Nurkka, Viiri, Littleton, & Lehesvuori, 2014), and for features of Toulmin's Argumentation Pattern (Erduran, Simon, & Osborne, 2004). ESRU model (Ruiz-Primo & Furtak, 2007) was used to code teacher utterances during argumentation and epistemic operators (Jiménez-Aleixandre, Rodríguez, & Duschl, 1999) helped to contextualize argumentation within the discipline of science. Although data analysis seems complex it placed argumentation within the pluralistic approaches of instruction in science. The analysis of qualitative data from classroom observation helped me understand where argumentation was used within the lesson (for example: introduction of idea, reinforcement of concept, discovery learning, lab data analysis) and how teachers and students engaged with each other's ideas during argumentation. In order to minimize observer paradox–particularly for students–I sat behind the students with the intention that being out of their field of view would eventually make them unaware of my presence. I neither sent any non-verbal (or verbal) feedback to the teacher as s/he is taught nor made unnecessary eye contact with the teacher but focused on listening and taking notes so that teacher was not distracted by my presence. At the end of the intervention I thanked the teachers and asked them if they wished to share their reflections from facilitating argumentation in their classes.

I did not personally know the teachers participating in the study. I did not have any supervisory or evaluative role at the school or in the science department participating in the study. During the process of interviewing teachers, I kept my focus on the research topic of argumentation – its use and implementation – and kept my interaction with the teachers professional. I developed specific interview questions (Appendix D) to elicit responses about teachers' understanding of, and plan to facilitate argumentation. Meetings with teachers were time bound and conducted so that it did not encroach on teacher's personal time. Since the school agreed to provide me with de-identified student responses on the SMTLS questionnaire, the school determined the timing when students would complete the instrument. Since the quantitative data is secondary data (collected by the school) the school coordinated administration of the instrument to accommodate my study. Pre argumentation administration of survey took place immediately after the one-on-one interview with teachers and post-argumentation administration of survey instrument happened immediately after the week of classroom observation.

The path a teacher uses to facilitate argumentation is determined by the content being taught, the nature of questions raised by students based on students' understanding of the topic and concept, and teacher's attention to and use of student responses. Most importantly, students can trigger a classroom dynamic that distributes ownership of learning among all players including the teacher. I kept an open mind to approaches (frequency, timing, and depth of conversation) teachers use to integrate argumentation in their instruction. I did not share my data with other faculty or the principal at school but I shared the analysis of classroom observations and my learning with participating teachers and asked for their input on the accuracy of my interpretation.

Methodology

This section lays out the plan for collecting data, drawing conclusions, and making possible recommendations. The **Institutional Review Board Number** for this study is 09-24-15-0308001 This approval expires on September 23, 2016.

Participant Selection Logic

Selection of the private K-12 high school, Delhi, India was made because this school encourages its teachers to practice progressive pedagogy and teachers actively explore instructional practices that have the potential to enhance student learning. Additionally, most of the published work on argumentation focuses on science classrooms in the West, and therefore my study of use of argumentation in a science classroom in India added data from another culture. Furthermore, teachers have a Masters degree in science and an undergraduate degree in science education, which I think may provide them with the depth of knowledge in the discipline and in education to structure their instruction to integrate argumentation. The heterogeneity of student abilities despite the fact that majority of them have progressed through school from elementary school and their socio-economic status (S. Kumar, School principal, personal conversation December 2013) provides for gender and student academic performance as covariates in the study, which I found more valuable than focusing on a homogenous group.

Students from grades ten and twelve have to prepare for the Central Board of Education Examination. Eleventh grade students in Indian system have specialized into science, business, and humanities courses, which therefore reduces the number of science students in grade eleven and their teachers who can participate in the study. Hence the ninth grade, which follows an integrated science program and which has about 90 students and four teachers, was selected to generate data for the study. Additionally, the SMTSL instrument (Tuan, Chi-Chin, & Shyang-Horng, 2005) is developed and validated for use with high school students, which further supported the convenience sampling of ninth grade class - teachers and students – for the study. Since all students in grade nine science class participated in the pedagogy of argumentation implemented by their teachers, the students represent complete collection sampling - a non-probability sampling. Complete collection sampling is also known as criterion sampling since all students meet the criterion (Teddlie & Yu, 2007) of having participated in argumentation the intervention implemented by their teachers. Figure 10 sequences the participant selection logic for the study.

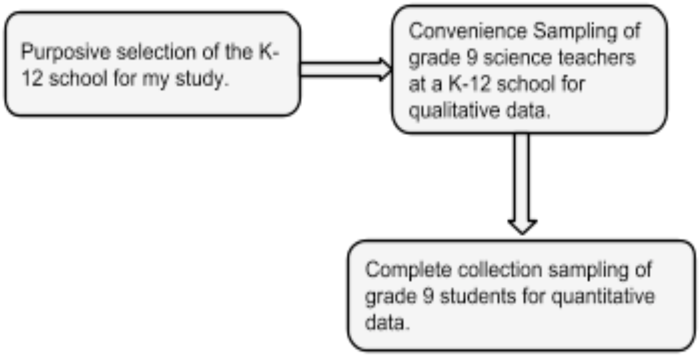


Figure 10. Mixed methods sampling approach for the study.

Participant teachers were contacted through the head of school and the department chair. Taking notes of classroom instruction (by visiting teachers) is a routine practice at school. The school uses these notes for professional development. Additionally, the school collects survey data from students to gauge the quality of their learning experience. Hence, the school took ownership to implement and share the de-identified data of the SMTSL instrument with me that they collected pre and post intervention.

In my mixed methods study, the four ninth grade teachers at the private K-12 school in Delhi worked together to coordinate instruction to ensure that the pace and content of syllabus coverage across sections was similar. Teachers collectively discussed argumentation and how to facilitate it in all grade nine science classes. I interviewed the teachers one-on-one to understand their individual plans to facilitate argumentation in their class. I observed each of the ninth grade cohort sections for one week, approximately four hours per section (total of twelve hours of instruction in all three sections together), to understand how teachers facilitated argumentation over the period of the week. Therefore, the sample size for qualitative study is different from a traditional qualitative study where multiple participants are interviewed once. I interviewed four teachers but collected about twelve hours of instructional time data.

My study was neither a case study nor an action-research, but emulated a qualitative analysis and hence instead of trying to identify the saturation for sample size, I focused on the quality of the discussions and interview, which had a "subsequent effect on achieving saturation" (Mason, 2010). Notes of classroom instruction (I sat in the three science classes while teaching was in session) of four teachers over the entire week provided a total of about twelve hours of instructional data for analysis of rhythm of discourse and analysis of argumentation.

Instrumentation

Collection of qualitative data began with one-on-one interviews with teachers on how they planned to facilitate argumentation. Interview questions about teachers' plans to integrate argumentation were open-ended and are included in Appendix D.

Classroom observations of teachers' instruction provided data on how each teacher facilitated argumentation in his/her class. I took extensive notes of classroom discourse during the time I observed class. Notes of classroom conversation for the entire week of observation were categorized in real time using the observation protocol included in Appendix E. This protocol allowed me, the researcher, to record the rhythm of discourse by characterizing teacher and student speech as teacher presentation (TP), teacher guided authoritative discussion (AD), teacher guided dialogic discussion (DD), and student initiation (SI) (Nurkka, Viiri, Littleton, & Lehesvuori, 2014). Analysis of each segment of teacher guided dialogic discussion (DD) or "argument space" provided information about “TAPping of argumentation” (Erduran, Simon, & Osborne, 2004). Characteristics of the dialogic discussion (DD) were recorded in a template (Appendix E) to document the sequence of teachers’ and students’ comments during each argumentation segment. Students’ use of epistemic operators (Jiménez-Aleixandre, Rodríguez, & Duschl, 1999) in their scientific reasoning and teachers’ utterances (ESRU model - Ruiz-Primo & Furtak, 2007) to engage students in discussions helped to identify the characteristics of the dialogic discussion (DD), which is the main focus of this study.

Quantitative data was collected from 90 ninth grade students of the four teachers whose classes I observed for the qualitative part of the study. Quantitative data was collected by the school using the Student Motivation Towards Science Learning (SMTSL) instrument (see Appendix H) pre and post intervention. Tuan Hsiao-Lin, Chi-Chin Chinb, and Shyang-Horng Shieh developed the SMTSL questionnaire, in 2005. Fourteen hundred junior high school students from central Taiwan, varying in grades, sex, and achievements, were selected by stratified random sampling to respond to the questionnaire. The Cronbach alpha for the entire questionnaire was 0.89; for each scale, alpha ranged from 0.70 to 0.89. There were significant correlations ($p < 0.01$) of the SMTSL questionnaire with students’ science attitudes ($r = 0.41$), and with the science achievement test in previous and current semester ($r_p = 0.40$ and $r_c = 0.41$). High motivators and low motivators showed a significant difference ($p < 0.01$) on their SMTSL. Students with high motivation showed a significant difference to moderate and low motivation students in the science learning value ($p < 0.01$). Students with high and moderate motivation showed a significant difference to low-motivation students in the performance goal and achievement goal. Students with high motivation showed a significant difference to low-motivation students in learning environment stimulation ($p < 0.05$).

The researchers undertook extensive field research and study of existing motivation scales to develop their science motivation scale. In addition to focusing on science motivation the SMTSL is designed for junior high school students, which makes it unique and appropriate for my study. The instrument has 35 items listed under six factors of motivation:

Self-efficacy. Students believe in their own ability to perform well in science learning tasks.

Active learning strategies. Students take an active role in using a variety of strategies to construct new knowledge based on their previous understanding.

Science learning value. The value of science learning is to let students acquire problem-solving competency, experience the inquiry activity, stimulate their own thinking, and find the relevance of science with daily life. If they can perceive these important values, they will be motivated to learn science.

Performance goal. The student's goals in science learning are to compete with other students and get attention from the teacher.

Achievement goal. Students feel satisfaction as they increase their competence and achievement during science learning.

Learning environment stimulation. The learning environment surrounding students, such as curriculum, teachers' teaching, and pupil interaction influenced students' motivation in science learning. (Tuan, Chi-Chin, and Shyang-Horng, 2005).

Each factor has inquiry and problem-solving features of science learning (from the Advancement of Science Learning) items on a 5-point Likert-type scale. Construct validity of the instrument was verified by factor analysis. Since this instrument measures both cognitive and the affective component to cognition, and also since it evaluates learning environment, particularly item 35 which relates to student involvement in discussion, it will serve my study well. The letter seeking permission from the developers of the instrument and their approval is attached in Appendix G.

This instrument was adapted for use in the study of middle school student motivation towards science in Turkey. Cronbach alpha reliability coefficient for the six factors of the SMTSL questionnaire was found to range from .54 and .85 and for the whole scale .87. Independent samples t-test was conducted to compare the SMTSL scores for males and females. There was significant difference in score for males (M=130.39, SD= 17.21) and females (M= 133.76, 16.07; t (657) = 2.59, p= .01). These results indicate that females have higher science motivation than males. The instrument was also adapted for use in Greece to study student teachers' motivation to study physics. Regarding the internal consistency of the scale, Cronbach's alpha coefficients revealed acceptable internal consistency for five out of the six scales (from .68 to .82). The science learning value scale had low internal consistency (**α 0**.52); however, an increased alpha (.65) appeared when item 18 (**"**In Physics, I think that it is important to learn to solve problems**"**) was removed. Moreover, regarding the performance goals scale's (**α 0**.69) internal consistency, the analysis showed an increased alpha (.75) when item 21 was removed. Guttman split-half coefficients also showed acceptable reliability for the four out of the six scales (from .62 to .77). Again, low split half reliability was found for the science learning value (.47) and the performance goals (.59) scales. Regarding the item-total correlation in each scale, it was between .28 and .63 in all the scales with two exceptions. Item 18 (science learning value scale) had an item total correlation of .04 and item 32 (environment stimulation scale) had an item-total correlation of .21. In both these instances the questionnaire was translated from English to the local national language, Turkish and Greek respectively. Additionally, the participants in the study belonged to an age group different from the junior high schoolers for who the original instrument was developed by Tuan et.al.

In 2012, Kooksal undertook a study using the instrument for evaluating advanced science students' motivation to study science. The scores on the SMTSL were found to have convergent validity with scores on attitude towards science scale used for the same group of students. The reliability of the test was analyzed by using Cronbach alpha value for internal consistency. The result of the analysis showed that alpha coefficient was .95 for the group of study. Considering the alpha value, it was concluded that the scores presented high internal consistency. In addition to the internal consistency analysis, difference in motivation toward science between female and male students was also investigated by independent-t test for finding supportive evidence for the results.

In 2010 a study used SMTSL instrument to investigate ninth grade science students' conceptual learning outcome and the effect of motivation on the learning. *Impact of* *student motivation in online learning activities* (2011) a dissertation at Nebraska University also used the SMTSL Earlier studies have affirmed the construct validity and reliability of the instrument which makes it a good instrument for my study.

Data Analysis Plan

Qualitative data collection started with recordings of one-on-one teacher interviews. The recorded qualitative interview data was transcribed and analyzed to understand how teachers planned to facilitate argumentation. The interview transcript was coded by (a) how teachers described and/or interpreted argumentation as a pedagogical practice (b) the area of instruction (for example: introducing a topic, reinforcement of concepts, interpretation of lab data, gauging understanding of an idea) where teachers see argumentation as beneficial for student learning and (c) how they planned to facilitate (teacher controlled/directed, organic/free flow) argumentation.

For the second set of qualitative data, the notes from classroom observation, I started with mapping the class discourse in a template that categorizes the events in the class as teacher presentation (TP), teacher guided authoritative discussion (AD), teacher guided dialogic discussion (DD), and student initiation (SI), to understand the rhythm of the discourse (Nurkka, Viiri, Littleton, & Lehesvuori, 2014). The criteria for identifying each of the categories: TP, AD, DD, and SI is shown in a rubric in Appendix E. The purpose of quantifying the classroom discourse for the week (for each grade nine section) according to its categories (TP, AD, DD, and SI) was to understand where during the lesson the dialogic discourse (DD) happens. Is argumentation being used during reinforcement of concepts, during inquiry-based activities, when a new topic is introduced, or when a student initiates the dialogic discussion?

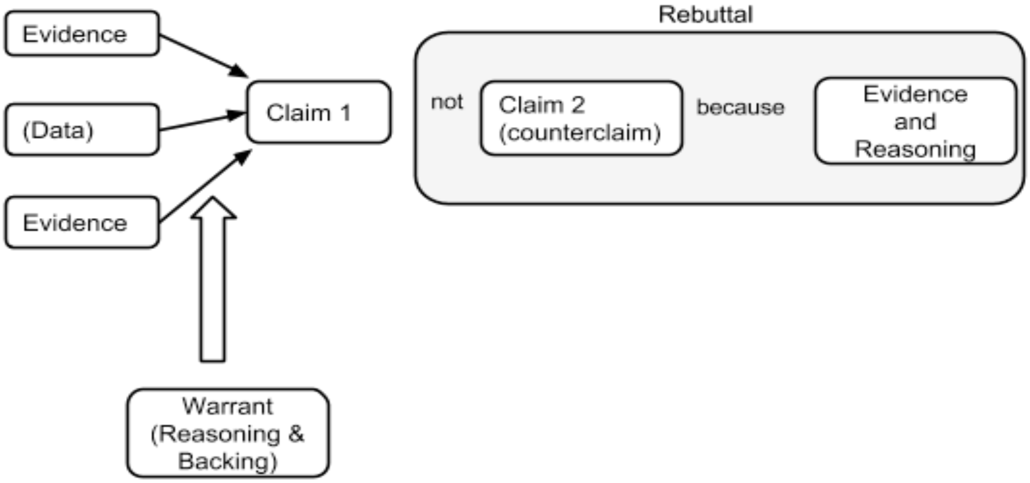


Figure 11. Features of TAP. From “A learning progression for scientific argumentation: Understanding student work and designing supportive instructional contexts,” by L. K. Berland & K. L. McNeill, 2010, *Science Education*, 94(5), p. 772. doi: 10.1002/sce.20402 Copyright © 2010 Wiley Periodicals, Inc. Reprinted with permission.

I then analyzed in detail each teacher directed dialogic dialogue (DD) segment for “TAPping of argumentation” (Erduran, Simon, & Osborne, 2004). Instead of focusing individually on each feature of TAP (Figure 11) to analyze the product of arguments, Erduran, Simon, & Osborne (2004) decided to group the features together in dyads, triads, and quads (see Figure 12 on next page*)* and recorded how often during the conversation each of these groups occurred. For example, a CDWR group contains a claim, data, warrant, and rebuttal. This group is considered a stronger argumentation sequence of conversation than a CDW or CDR group because it contains a rebuttal along with a warrant while the other two groups focus only on a warrant or a rebuttal along with a claim based on data.

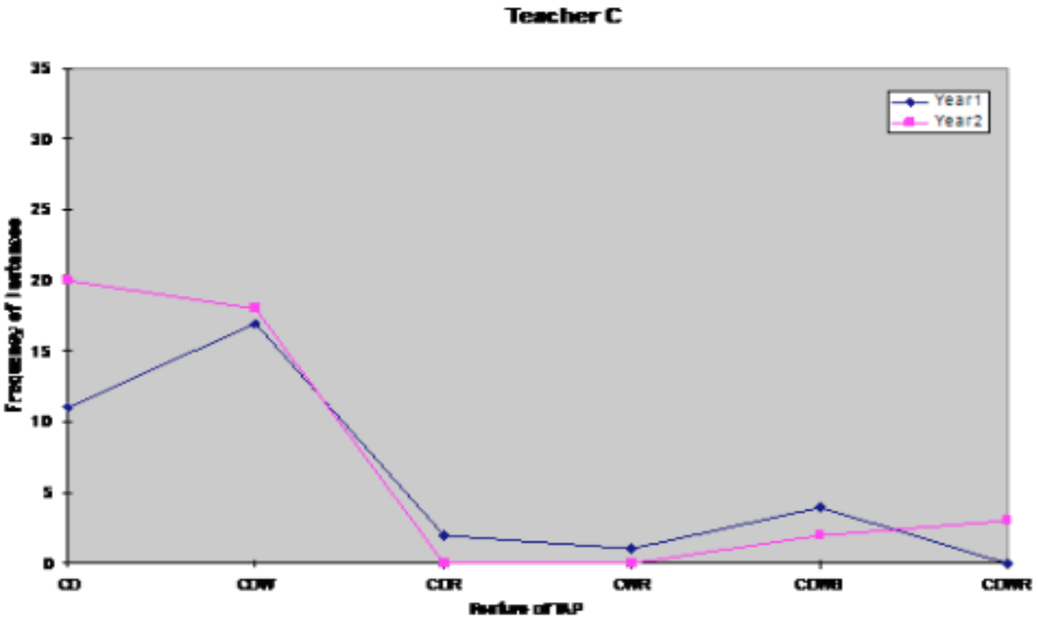


Figure 12. Distribution of TAP features (TAPping). From "TAPping into argumentation: Developments in the application of Toulmin's Argumentation Pattern for studying science discourse," by S. Erduran, S. Simon, J. & Osborne, 2004, *Science Education*, 88(6), p. 927. Reprinted with permission

Argumentation in science class must contain elements of epistemic operators (Jiménez-Aleixandre, Rodríguez, & Duschl, 1999) specific to the discipline to identify warrants, claims, and backing (TAP features) in scientific reasoning (See Figure 3, pp. 50). Hence, I revisited notes from classroom observation to check for students' appeal to these epistemic operators during their responses. Finally, I also used the ESRU model (Ruiz-Primo & Furtak, 2007) to decipher teacher utterances – how they worded their questions and comments to engage students in conversations in class. A template for interpreting student and teacher comments to contextualize argumentation in the science class is shown in Appendix F. Figure 13 outlines the qualitative data collection plan for the study.

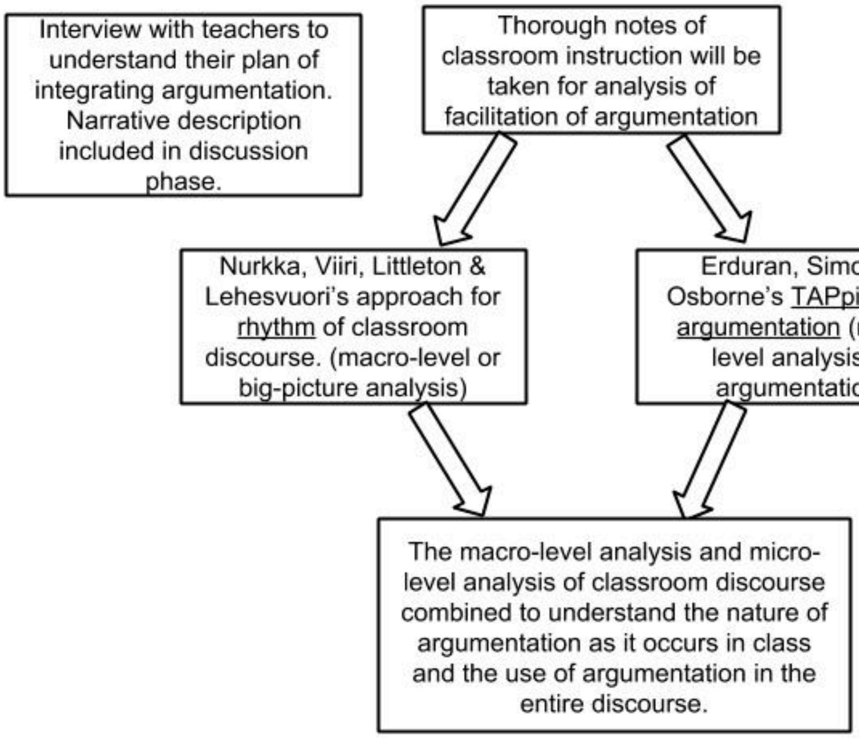


Figure 13. Qualitative data analysis plan.

Statistical analysis of (SMTSL) instrument of students' perception of their motivation to study science pre and post intervention provided quantitative data for the study. Statistical tests include the following: paired sample t-test for the entire group; independent sample two sample t-test for difference in means pre and post intervention by gender; ANOVA on the variation of means of low, middle, and high achievers, pre and post intervention; and Multiple linear regression model on the difference scores with qualitative predictor of gender and achievement. Achievement levels and boundaries will be defined objectively for this analysis.

Qualitative and quantitative data were analyzed separately. This separate analysis is justified on the basis that each component (qualitative and quantitative) answers a different question. Additionally, findings from each component helped to expand understanding of argumentation use and impact. Findings from the two categories of data were integrated during the discussion and interpretation phase.

Threats to Validity

Threats to internal validity for the quantitative study come from multiple sources. The one group pre-post test design suffers from threat to internal validity due to history and maturation. The difference in the scores on the motivation scale could be either due to the intervention or due to the increased understanding over time of science concepts among students or due an external factor beyond the control of the experimenter, for example the instructor for a class may change while the study is in progress. Similarly, one group design can suffer from threat to internal validity due to testing. Test items can sensitize students to certain ideas and hence impact their performance on the post-test. Additionally, since the SMTSL instrument uses students' self-reported data, their perceptions can vary based on external stimuli not related to the quality of instruction in class. Experiment mortality is a potential threat to internal validity if a few participants are not present on the day of completing the pre and post intervention survey, or if they are unwell and miss classes for some period of the intervention. In day schools there can be different students absent on different days and that can add threat to internal validity as well.

Threat to internal validity due to statistical regression to the mean probably does not exist because the survey is based on student perceptions and is not a cognitive test. However, if a student has an abnormally good or bad day during either the pre or the post test there is a possibility that the responses will be skewed.

The greatest threat to external validity comes from the fact that this study is run in a single school. The fact that teachers are experts in their discipline and have a degree in education is a unique characteristic that also limits generalizability of findings. Students may come from a range of socio-economic background but culturally education is regarded as a precursor to upward social mobility and therefore educational opportunity is a strong extrinsic motivator. Additionally, students have a consistent and similar background of science knowledge unlike the USA where 9th graders may come from different middle schools and hence with different science background. This population validity may make it difficult to generalize the study to other contexts.

Of the six periods in a week, every class receives two periods of instruction in physics, chemistry, and biology. Additionally, each class has at least two science teachers in a week. Therefore, the teacher is a covariate, along with other covariates like gender and student achievement. While analysis by student gender and achievement is possible, it is not possible to separate student responses by teacher. One teacher's method or personality may overshadow another teacher's approach in student responses to the questionnaire. Additionally, even if the quantitative study shows a significant change in student motivation due to argumentation in science classroom it may not suggest a cause-effect relationship between the two variables: argumentation and motivation to study science.

Statistical conclusion validity is the degree to which conclusions about the relationship among variables based on the data are correct or reasonable. A large sample size leads to a high statistical power (0.8 or higher) and increases statistical conclusion validity. Additionally, a high confidence level (alpha of 0.05 or 0.01) decreases the probability of a Type I error. Purposeful sampling of the four ninth grade science teachers, which led to convenience sampling of their 90 science students—all of whom were expected to complete the motivation survey—increased the sample size and power of the statistical findings. Additionally, using an alpha of 0.05 or less to reject the null hypothesis decreases the chances of Type 1 error. However, decreasing Type I error can lead to an increase in Type II error, and therefore I decided to not use an alpha of 0.01 for hypothesis testing. Furthermore, using the SMTSL instrument with a Cronbach alpha of 0.089 enhanced the reliability of quantitative analysis.

Issues of Trustworthiness

One of the issues with qualitative research is that data is collected from people by the researcher who is also a human instrument, and hence personal characteristics, preferences, and interpretations can lead to multiple realities. Guba’s (1981) four criteria of trustworthiness, credibility, transferability, dependability and confirmability are important for evaluating the worth of qualitative studies. I ensured credibility of my study by (a) accurately documenting every communication I had with the teachers as I discussed their lesson plan to implement argumentation in instruction, and (b) by using established methods of quantifying classroom discourse. I used the coding method adopted by Nurkka, Viiri, Littleton, & Lehesvuori (2014), to analyze rhythm of classroom discourse, which placed argumentation within the context of other activities during instruction, and Erduran, Simon, & Osborne (2004), TAPping of argumentation approach to identify TAP features (Data, Claim, Warrant, Rebuttal, Backing) during argumentation, with particular emphasis on the epistemic operations during warrant, rebuttal and backing as used by Jiménez-Aleixandre, Rodríguez & Duschl (1999). Using overlapping discourse analysis techniques also enhanced the dependability of my qualitative findings.

Sharing my results and analysis with the participants to get their feedback on the accuracy of my interpretation helped in establishing credibility of my findings, particularly in the absence of another outside researcher to audit my work. However, teachers' lack of depth of knowledge and skills in dissecting classroom discourse could be limiting in their ability to provide input during member-check.

Using thick descriptions about how teachers facilitated argumentation, the cultural, social and educational context of the school in which the study was undertaken, any challenges the study provided, and of my analysis of the data, enhanced transferability of the qualitative design. Other researchers, undertaking similar studies in similar contexts will be able to draw on my work if the narration is detailed and strong. Identifying my biases and assumptions, and discussion of how limitations of the methodology will impact my study will enhance confirmability of the research as the data can now be attributed to participants.

Ethical Procedures

A school letter of cooperation was obtained from the principal to conduct this mixed-methods study (see Appendix A). Authorization from the Institutional Review Board (IRB) at Walden University was sought to use classroom observations in this research study. Additionally, I informed IRB of the arrangement that the school took ownership of the SMTSL survey. The school collected quantitative data and shared the de-identified data from the survey with me.

The population of four teachers at the (K-12) school participated in the study; all teachers as participants completed an informed consent form (see Appendix B) discussing guidelines of their participation level, involvement, and procedures of the study. Information on the informed consent forms includes: (a) overview of the study, (b) specific time requirements, (c) voluntary status noting a participant may leave at any time during the study without consequences, (d), confidentiality agreements, and (e) a discussion of no compensation for participating. This information will be reviewed and signed by the participant before research begins. The one-on-one interviews with teachers were scheduled at a time chosen by each individual participant and were conducted via Skype.

In the event that the selected (K-12) school declines to participate, which I do not anticipate, I had planned to complete a Request for a Change in Procedures form with the Institutional Review Board of Walden University. I was aware that approval would be sought from this new target principal and IRB before conducting the study. This is the procedure laid out by IRB and I expected to follow it in case the need arose.

De-identified quantitative data provided by the school and all notes of qualitative data are labeled and saved with password access so it is not accessible to anyone other than me and my committee members if they request to see it. All information remained confidential and was not left unattended during the study. Pseudonyms are used in all written materials relating to this dissertation to protect individual privacy in shared and published data. All materials associated with this study will be kept safely with me for a period of 5 years before discarding it.

Summary

In chapter 3, I have discussed how the mixed methods research provides rich qualitative description about how teachers plan to facilitate argumentation. Quantitative data collected from student responses to the SMTSL will provide additional perspective on changes in student motivation to study science as a result of participation in argumentation. The models used by Nurkka, Viiri, Littleton, and Lehesvuori (2014), Erduran, Simon, and Osborne (2004), and Jiménez-Aleixandre, Rodríguez and Duschl (1999) to quantify classroom discourse were discussed and the data analysis plan described how I used these models to analyze my data to understand how argumentation dominates or blends in with other instructional approaches in class. Student voice, provided through responses to the motivation instrument will be analyzed using inferential statistics to further understand whether participant teachers' and the researcher's trust in the value of argumentation during instruction is validated by the learner.

Issues of validity of quantitative data and trustworthiness of qualitative data were also discussed. Validity of the SMTSL instrument was discussed by referencing multiple studies that adapted the instrument for their study. Validity of the adapted instruments agreed with the validity of the original instrument, making it a valid instrument for my study as well.

In Chapter 4, I reintroduce the purpose and questions of this study; I also describe the research site, organizational conditions influencing participants, participant demographics, data collection, and data analysis and provide evidence of trustworthiness of the results.

Chapter 4: Results

The purposes of this mixed methods concurrent nested study were to understand how teachers planned for and facilitated argumentation and to explore how argumentation consequently impacted student motivation in science class. The research question that guided this study is, How does the use of argumentation in science instruction motivate students in science class? This one question was subdivided into three sub-questions, two of which were qualitative and one of which was quantitative.

Qualitative questions:

RQ1. How do teachers plan to incorporate argumentation in their instruction?

RQ2. How does argumentation occur in the classroom in terms of epistemic operators?

Quantitative question:

RQ3. To what extent does student motivation in the science class change after students engage in argumentation in class?

This chapter begins with a description of the setting for the study. I then discuss my teacher and student participants and explain the data collection processes that I followed. Next, I discuss data that were collected as well as the analysis process that I used. After these preliminaries, the results are presented. I present the findings from my one-on-one interviews with teachers, followed by the results from my classroom discourse observations. Next, the quantitative analysis of the pre and post motivation surveys are presented. I conclude this chapter by providing evidence of trustworthiness:

validity, transferability, dependability, and confirmability; followed by a summary of the chapter.

Setting

The setting of this study was a K-12 private school in Delhi, India. Data were collected from the four science teachers who teach ninth grade science at the school. Ninth grade science teachers consult with one another to ensure that the pace of the course across sections is uniform. The teachers also use similar worksheets to ensure consistent testing across sections. The school encourages its teachers to use innovative pedagogy with the objective of encouraging active student participation in learning. The integrated science curriculum introduces students concurrently to topics in biology, chemistry, and physics. During the week of my classroom observation and data collection, participants studied the following topics in their classes:

- Animal tissues (biology class),
- Separation of substances (chemistry class), and
- Force and Momentum (physics class).

Two science teachers also teach one section each of Grade 9. One of these teachers has an advanced degree in physical science while the other one has an advanced degree in biological science. All teachers also earned a Bachelor's of Education degree.

Data Collection

For this concurrent nested mixed methods study, qualitative and quantitative data were collected within an eight-day time frame. Teachers who were experimenting with intentionally using argumentation in their instruction were recruited for the study. These teachers were interviewed individually, and their classes were observed for a week. Telephone interviews with the teachers took place on the weekend prior to classroom observation. Detailed notes of instruction and conversation during class were taken on a classroom discourse grid that I developed (see Appendix D). Each morning <during your data collection? the academic dean presented the day's observation schedule to me. I arrived before the start of each class and waited for each teacher to welcome me before I took my seat at the back of the room. Sitting on the last bench at the back of the class with the intention to avoid creating an observer paradox during data collection, I took careful notes on my laptop as the class was in session.

Timed to accommodate my study, the school collected quantitative data from students using the SMTSL instrument (see Appendix H). Pre argumentation survey responses were collected by the school on the Friday before the week of class observation, and post argumentation survey responses were collected on the end of the day on Friday after my last classroom observation. The school provided me with de-identified, but matched pre and post argumentation data for all students who took the survey. Of the 90 students in Grade nine, 10 students did not complete either the pre or post surveys as they were away from school on both days, 11 took the survey only on the post argumentation day, and 2 took the survey only for the pre argumentation day. The sample size of 67 students from a population of 90 grade nine students (whose four science teachers provided qualitative data on argumentation) did not negatively affect the power of the analysis.

Table 1.

Weekday Classroom Observation Schedule for Each Cohort Section

	Monday	Tuesday	Wednesday	Thursday	Friday
Cohort section			Subject (Teacher)		
9A	Physics (Teacher A)	Biology (Teacher B)	Chemistry (Teacher B)	Chemistry Lab (Teacher B)	Physics (Teacher A)
9B	Physics (Teacher C)	Physics (Teacher C)	Biology Lab (Teacher D)	Chemistry lab (Teacher C)	Biology (Teacher D)
9C	Physics (Teacher A)	Biology lab (Teacher D)	Chemistry Lab (Teacher A)	Biology (Teacher D)	Chemistry (Teacher A)

These ninth grade students were divided into three groups or sections, identified as 9A, 9B, and 9C. Each section followed an integrated science curriculum with instruction time per week devoted to three different topics (biology, chemistry, and physics) concurrently. Each section was taught by two teachers - one with a degree in biological sciences and the other with a degree in physical sciences. Thus, each ninth grade student learned from two science teachers throughout the year. This arrangement of two teachers sharing instruction time in class necessitated coordination between teachers to ensure syllabus coverage and to address student needs.

Each of the three sections of students received 4 hours of science instruction per week, which averaged to one hour forty-five minutes per subject, but the academic schedule was flexible and provided three different time slots: 30 minutes, 45 minutes, and 60 minutes, meaning students' exposure to each subject varied from week to week. The 60 minute time slot was created by combining a 45 minute slot with 15 minutes of break time and was used for labs or for long tests. Similarly, a 45 minute class was on some days split into a 30 minute class and 15 minute break. If the instructor taught two subjects in a class (for example teacher B teaches Biology and Chemistry to class 9A) then the teacher got 2.5 hours of instruction time per week with the class, and the teacher who taught only one subject (for example teacher A teaches only physics to class 9A) got 1.5 hours of instruction time per week with the class. The 2.5-hour instruction time gave control to the instructor to allocate time between the two subjects based on class needs. It is important to note that the flexibility in scheduling science instruction allowed for each section receiving different amounts of instruction time for each subject. For example, cohort section 9A did not have a Biology lab scheduled for the week. Since Teacher B taught both biology and chemistry to the cohort section 9A, she had the flexibility to interchange her lab class between chemistry and biology. Additionally, since all the ninth grade cohorts were discussing application questions in physics, they did not have a physics lab scheduled for the week.

To summarize the data collection procedure: the school collected student responses on the SMTSL instrument on the Friday before the week of classroom observations; I interviewed the four ninth grade science teachers on the weekend before the week of classroom observations; I sat through the science classes from Monday through Friday, and then the school collected another set (post-argumentation) of student responses on the SMTSL instrument on the last day (Friday afternoon) of my classroom observations. The school shared the quantitative data from the survey—de-identified and matched pre and post argumentation—with me. I had an exit interview with the teachers at the end of the week of classroom observations in order to thank them for inviting me into their classes. I also thanked the academic dean for her support in collecting quantitative data for my study. The entire process of data collection took eight days: Friday-to-Friday.

Data and Data Analysis

The data presentation is ordered according to the research questions. Qualitative data (interviews and observations) are presented first followed by quantitative data (pre-post motivation survey results).

Qualitative Data: One-on-one interviews

Research Question: *How do teachers plan to incorporate argumentation in their instruction?*

The one-on-one interview used the interview questions (Appendix D) I developed. Since planning for argumentation was a collaborative effort, teachers spoke frequently in unison and their responses to the interview questions were similar. A summary of teacher responses follows below each of the questions asked of each teacher during the interview.

1. *Can you describe the unit you will be teaching this week in your science class? What are some of the difficult ideas in this topic for students? Why do you think these ideas are difficult for the students?*

   Each teacher outlined the topic s/he planned to teach during the week of observation. Teacher B stated that, “the current unit on tissues builds on the difference between animal and plant cells students studied in grade eight. Discussions in class will require students to draw on their prior knowledge of tissues." Teacher D indicated that the lab on separation techniques follows the unit of physical and chemical properties that the class "studied last term." Teacher A said that, "the class has recently studied Newton's laws of motion" and the week's activities will require students "to apply the laws of motion to describe physical behavior." All teachers were confident that the level of challenge of the units for the week was appropriate and, according to teacher C, "builds on students' prior learning." However, teacher D was aware that handling apparatus for fractional distillation and sublimation could be difficult for students as they had not seen the apparatus earlier.

2. *Can you explain why the team of ninth grade science teachers decided to experiment with using argumentation in their classes?*

   The team of ninth grade science teachers decided to experiment with using argumentation in their classes in general to interact more intensively with students and to give the students a greater role in the class discourse. Whereas teacher A wanted to "engage students more in dialogue," teacher D was keen to integrate, "collaborative learning activities" for students. Teacher B said that, "communication skill is essential in the current work environment and argumentation will help to improve students' communication skills."

3. *In your mind, how would argumentation play out in class?*

   All teachers pointed out that they would call upon students by their ID numbers in order to randomize which student responds to a question. Teacher C indicated that although the worksheets for in-class discussions in his class are identical to those that Teacher A will use in her class, "based on student responses and student questions during instruction, the flow of conversation in both teachers' classes would vary."

4. *How do you (and the team of ninth grade teachers) plan to incorporate argumentation in class? How will your class for this week be different from/similar to your classes in the last week? Month?*

   Teachers described their collective effort to engage students in classroom discussion. Teacher D believed that argumentation has to be directed by the instructor in order to, "ensure that classroom conversation remains focused on the topic and for progression of learning." All teachers interviewed agreed with teacher B that since during argumentation, students provide scientific justification to support their responses, "argumentation can take place in a variety of contexts of learning in science – during review of material, lab-work, during instruction of a new idea, or initiated by a student question." Additionally, since the science department follows a spiraling curriculum—each of the topics builds on ideas introduced in the previous year—teachers felt that the natures of the questions teachers ask can prompt students to reflect on their previous knowledge, particularly when the teacher introduces a new topic. Teacher C was confident of students' ability to, "apply Newton's laws to describe motion," since students had practiced questions on the topic in the previous week. Teacher B was however worried about losing instruction time if students were "engaged in too much argumentation."

5. *Can you tell me if you anticipate any challenges in facilitating argumentation in your class?*

   Teachers stated that despite their effort, they may not be able to engage every student during argumentation. Teacher B was concerned that, "some students may be distracted by too much conversation," while teacher A stated that syllabus coverage is a reality that cannot be overlooked and therefore the "time spent on eliciting student responses and using these for promoting learning will be managed" to find the balance between argumentative learning and didactic instruction. Teacher C was nervous that he may not have the skills to maintain a meaningful discussion where "all students participate," but he, like his other science colleagues, looked forward to the experimentation with argumentation in his class.

6. *Is there anything else you would like to share with me about your class before I sit in your class? Would you like me to sit at a particular place in the class?*

   With respect to where I should be seated in class for data collection, the teachers did not have a preference. Since the school follows a spiral curriculum, teachers stated that none of the topics being covered was totally new for the students. The topics were building on ideas learned by the students in the previous grade or an earlier term. Vertical coordination across grades and horizontal coordination across all sections of a grade provided continuity and minimized gaps in students' learning of material.

It was evident from the interviews that the ninth grade science teachers had put in thought to facilitate argumentation in their class. Their conception of argumentation was a teacher-directed dialogue that was focused on the lesson and allowed for conversation among students, but was timed to ensure that the syllabus coverage was not compromised. The only concern teachers expressed was that, "all students" may not either participate during argumentation or find argumentation beneficial for their learning.

Qualitative Data: Classroom Observations

Research Question: *How does argumentation occur in the classroom in terms of epistemic operators?*

Classroom observation data is presented for the three sections: 9A, 9B, and 9C, each of which includes all three subjects—biology, chemistry and physics. For each of these three sections, I have created one *classroom discourse map* per topic. The discourse maps sometimes include discourse that spans more than one day of class in order to illuminate the landscape of argumentation for the topic, rather than limiting my attention to small chunks of time defined by a class period. The purpose of the discourse map is to represent the rhythm of conversation within each discipline through the week (Nurkka, Viiri, Littleton, & Lehesvuori, 2014).

In each classroom discourse map, conversation is categorized as *teacher presentation* (TP), *teacher-directed authoritative discussion* (AD), *teacher-directed dialogic discussion* (DD), and *student initiation* (SI). Appendix E lists the criteria for categorizing conversations as TP, AD, DD, and SI. Detailed directions for how to read the classroom discourse map are provided after the first map, Figure 14.

Following each map is a *dialogic discourse (DD) table* that categorizes the argumentation part of the discourse using to the ESRU model for teacher utterances (Ruiz-Primo & Furtak, 2007) and the TAP features (and epistemic operators) for student responses. The tables' purpose is to "zoom in" on the part of the classroom conversation that is categorized as teacher-directed dialogic discourse. Student responses are presented in the column to the right and corresponding to the questions raised by the teacher. Detailed directions for how to read the dialogic discourse (DD) tables are provided after the first such table, Table 2.

Following the classroom discourse maps and DD tables for the three topics in each of the three sections is a figure that quantifies the distribution of TAP features overall (see Figure 23) For this figure, I decided to combine TAP features across topics for each section, since I am interested in looking at student experience in science argumentation independent of the science discipline (biology, chemistry, and physics) or the teacher.

Finally, in this section of classroom observation results, I combined all three sections to see TAPping for the week of argumentation for all ninth grade science students. The presentation of the data begins with section 9A.

Biology 9A science classroom discourse. For the biology portion of section 9A, as shown in Figure 14, students engaged in the Chocolate Factory Cell Function Analogy activity (based on a worksheet) that built on the previous week's instructions on cells.

The teacher presented the worksheet and explained the activity, and then the students worked individually for ten minutes. This 10-minute period was characterized as teacher presentation (TP), as indicated by the horizontal line corresponding to the TP on the Y-axis in Figure 14. For the next 25 minutes, students worked in groups without teacher interaction, which was characterized as student-initiated discourse (SI) and indicated by a horizontal line at the SI level of the Y-axis. Finally, students shared their answers with the whole class for five minutes. This five-minute period was categorized as dialogic discourse (DD). The dialog between teachers and students was short and responses from students represented retrieval of information based on definitions of parts found inside the cell. While most of the conversation in class was directed by the teacher and based on recall of information, there were instances in which the instructor picked up on student responses and required deeper analysis from the class, which are shown documented in Table 2.

Tuesday

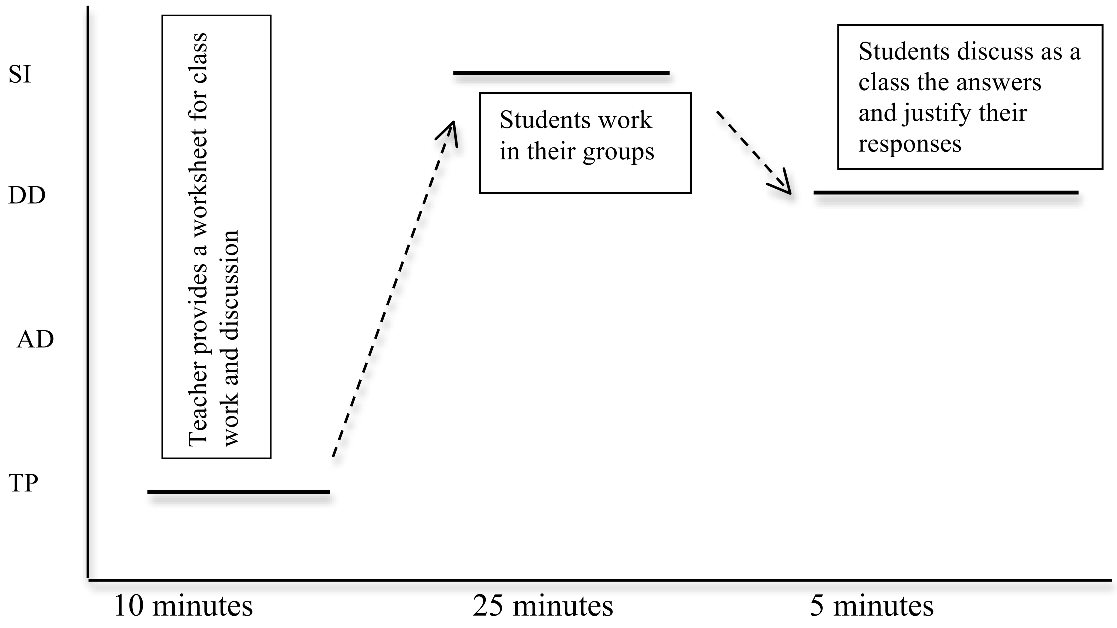


Figure 14. Classroom Discourse Map – 9A Biology

Table 2 can be read from left to right: teacher question→ESRU factor in the specific question→student responses to this specific question, and→ TAP features (epistemic operators) in the specific answer. The teacher's first question in the first column was, "Student 1 has identified the machine in the chocolate factory to Ribosomes in a cell. However, the chocolate making machine could also be Chloroplasts. What do you think?" The ESRU factor that the teacher employs in this case is "use" because the teacher *uses* the response from Student 1 to promote discussion among other students. Moving right across the table, the next column includes the verbatim reply from student 2: "Since the diagram of the cell does not contain a cell wall, the cell is an animal cell and not a plant cell. Therefore, the organism is a Ribosome and not a chloroplast which is found in plant cells only." The TAP features being used by the student here are *warrant and backing for a claim*, with cognitive reasoning (the epistemic operators) that appeal to attributes of the cell, as is indicated in the last column of Table 2.

Below Question 1 is the second teacher utterance or question in the conversation, which is also categorized as an instance of the teacher using the student response to promote discussion, but the student's reply is an instance of the *claim and backing* with cognitive reasoning that draws on analogy between the cell and the manufacturing unit in the factory, as well as appeals to consistency of knowledge; as opposed to the warrant and backing used by Student 2.

Table 2

Analysis of Teacher Directed Dialogic Discussion in Biology (Class 9A)

Teacher comment/question		Student responses	
Teacher comment verbatim:	ESRU factors (Elicits, Recognizes, Uses)	Student comment verbatim:	TAP feature/s (epistemic operator)
Question 1: "Student 1 has identified the machine in the chocolate factory to Ribosomes in a cell. However, the chocolate making machine could also be Chloroplasts. What do you think?"	The teacher: Uses response from student 1 to promote discussion among other students	Answer 1: Student 2: "Since the diagram of the cell does not contain a cell wall, the cell is an animal cell and not a plant cell. Therefore, the organism is a Ribosome and not a chloroplast which is found in plant cells only."	Student 2: Warrant and Backing for a Claim (Appeal to Attribute)
Question 2: "Why is the machine shop not equivalent to the chromosome or the DNA as stated by some of your classmates?"	The teacher: Uses students' responses by encouraging them to explore their own ideas.	Answer 2: Student 3: "Both the chromosome and the DNA are not cell organelles. The machine shop is analogous to the Nucleolus as it furthers the function of the ribosome."	Student 3: Claim and Backing (Analogy, Consistency with other knowledge)

From table 2 it is evident that the teacher in Biology 9A uses student responses to ask follow-up questions, and students appeal to the characteristics of cells and their prior knowledge (epistemic operators) to provide scientific reasoning. All of the following DD tables can be read in this way.

Chemistry 9A science classroom discourse. The chemistry unit for the week focused on separation techniques of mixtures. During Wednesday's class the teacher demonstrated separation techniques and her questions to students were designed to help them identify techniques of manipulating the apparatus to collect reliable data. Thursday's class was a lab class where students worked in groups but there was no whole class discussion.

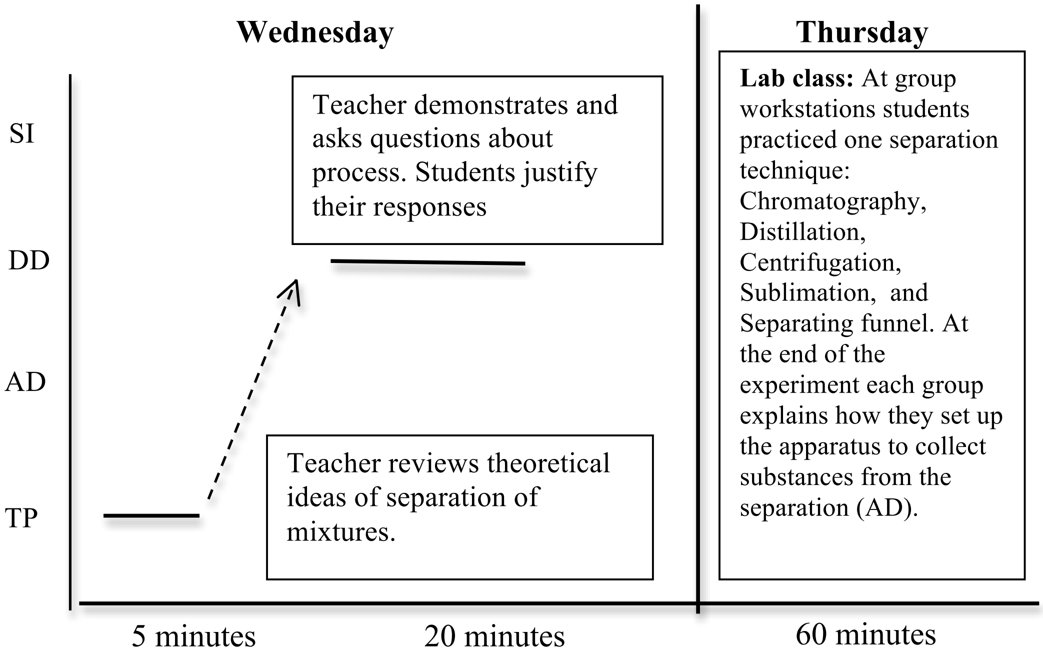


Figure 15. Classroom Discourse Map: 9A Chemistry

As shown in Figure 15, on Wednesday, the chemistry teacher spent the first five minutes of class reviewing ideas of separation of mixtures. As indicated by the horizontal line in the figure, these five minutes are classified as teacher presentation (TP). The teacher then spent 20 minutes of class time to demonstrate separation of mixtures and asked questions that required students to justify (using science principles) their responses and also created situations that engaged students in conversation with each other. These 20 minutes are classified as teacher directed dialogic discussion (DD). It is the 20-minutes of dialogic discussion (DD) that is treated as argumentation and analyzed in Table 3. The Chemistry teacher used the argumentative strategy of *elicitation* by asking students to formulate a scientific explanation for lab procedure. The students responded twice with cognitive reasoning that drew on the epistemic operator of *causality*—establishing a cause-effect relationship between an action and its outcome—and once with *deduction*. Additionally, student responses were supported with warrants and backing, representing a deep level of thinking.

Table 3

Analysis of Teacher Directed Dialogic Discussion in Chemistry (Class 9A)

Teacher comment/question		**Student responses**	
Teacher comment verbatim:	**ESRU factors (Elicits, Recognizes, Uses)**	**Student comment verbatim**	**TAP feature/s (epistemic operator)**
Question 1: You observe that the water stops flowing out of the funnel after some time. Why do you think that when you release the cork on top of the funnel the water starts flowing again?	The teacher: **E**licits student responses by asking them to formulate a scientific explanation for lab procedure.	**Answer 1:** Student 1: The vacuum created in the closed funnel prevents the water from flowing **Student 2**: When you opened the cork air entered the funnel and air pressure allowed the water to flow again.	Data, Warrant, Backing (Causality)
Question 2: Why does oil float on water?	The teacher: **Elicits** answer to check comprehension	**Answer 2:** Student 3: Because oil is less dense than water.	Warrant/Backing (Causality)

Teacher comment/question		**Student responses**	
Teacher comment verbatim:	**ESRU factors (Elicits, Recognizes, Uses)**	**Student comment verbatim**	**TAP feature/s (epistemic operator)**
Question 3: Can the separating funnel be used to separate a mixture of salt and ammonium dissolved in water?	The teacher: **E**licits responses to make predictions.	**Answer 3:** **Student 4**: No because the two solutions dissolve in each other. The technique can only be used to separate immiscible liquids.	Warrant & Claim (Deduction)

Physics 9A science classroom discourse. For physics in section 9A, Monday's lesson was a review of Newton's laws of motion and Friday was devoted to group work followed by whole class discussions on concepts of Newton's laws. Friday's whole class discussion is considered dialogic discourse and analyzed in Tables 4, 5, and 6 (for questions 1, 2, and 3 respectively). The three questions are included in Appendix I. On Monday teacher presentations (TP) and authoritative dialogue (AD) defined the discourse for most of the class with about five minutes of dialogic discourse (DD) where students engaged with each other's ideas, but Friday's class witnessed a huge chunk of 30 minutes of DD (Figure 16).

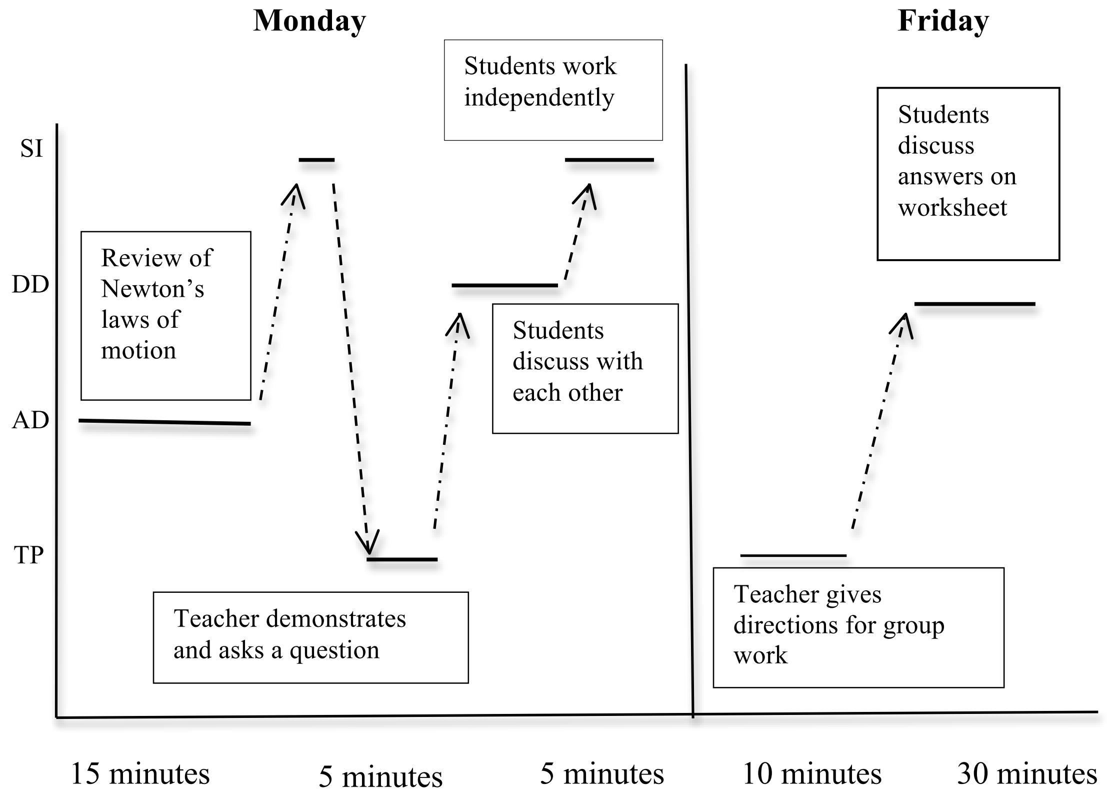


Figure 16. Classroom Discourse Map: 9A Physics

During the dialogic discussion the teacher elicits responses from students and encourages them to evaluate options, provide scientific reasoning, interpret information, and formulate scientific explanations. She uses student responses to promote further discussion and prompts them to elaborate their responses. Finally, by summarizing and rephrasing student responses, the teacher recognizes students' participation. Students' cognitive reasoning generally draws on the epistemic operator of deduction and causality. There are a few rebuttals that are supported by a new claim and an accompanying explanation. Overall, the dialogic discourse was animated and purposeful and evidenced students' active learning in the class. The conversations in class were reflective of development of collective understanding of Newton's laws of motion.

Table 4

Analysis of Teacher Directed Dialogic Discussion in Physics (Class 9A) – Question 1

Teacher comment/question		**Student responses**	
Teacher comment verbatim	**ESRU factors (Elicits, Recognizes, Uses)**	**Student comment verbatim**	**TAP feature/s (epistemic operator)**
Can someone respond to question 1?	The teacher Elicits responses to evaluate options and to provide scientific explanations. Uses responses to promote discussion among students, **R**ecognizes the correct response by rephrasing student answers.	**Student 1**: It is A	Claim (by student 1)
		Student 2: I think option B is correct.	Claim (by student 2)
Explain. Why do you think B and C are incorrect?		**Student 3**: I don't think C is correct because the car has a greater mass and therefore exerts a larger force on the insect than the force the insect exerts on the car.	Claim followed by Warrant. (student 3) (Induction)
What about C?		**Student 4**: I think C is correct because the forces that the car and the insect exert on each other are action-reaction pair as stated by Newton's 3rd law. The car and the insect exert equal and opposite forces on each other.	Student 4: Rebuttal (to student 3's response) and backing. (Deduction)
At the end of the entire discussion the teacher brings together the ideas and states: The correct answer is C. The car and the insect exert equal and opposite forces in each other and therefore the change in momentum for each is identical.		**Student 2**: B is correct because the car has a higher mass and velocity and than that of the insect and so the insect experiences higher impact than the car.	Student 2: Rebuttal to student 4, with warrant for his/her answer. (Induction)
		Student 1: But, if the impact on the insect is higher than that on the car then option A is correct because the change in momentum depends on impact force (Newton's law of momentum)	

Table 5

Analysis of Teacher Directed Dialogic Discussion in Physics (Class 9A) – Question 2

Teacher comment/question		**Student responses**	
Teacher comment verbatim	**ESRU factors (Elicits, Recognizes, Uses)**	**Student comment verbatim**	**TAP feature/s (epistemic operator)**
The teacher directs group members to share their answers. Along the way the teacher affirms students correct responses. At the end of the discussion the teacher asks the class if there are further questions. With no additional questions the class moves on to the next question.	The teacher **E**licits responses from students by asking them to Interpret information and to formulate scientific explanations **U**ses student responses to Promote discussion among students' ideas and conceptions and to promotes students' thinking by asking them to elaborate their responses (asks why? What?). **R**ecognizes student responses by Summarizing (recognizes) students' responses	**Student 1**: (i) is false as motion is **perpendicular** to the ground. Force of gravity pulls the diver downwards. Other students agree vocally.	(i) Rebuttal followed by a new claim (by student 1) and a warrant (Induction/Causality)
		Student 2: (ii) is correct. On impact with the water the diver experiences a force equal to the force with which she hits the water. This force can be greater than gravitational force.	(ii) Claim (by student 2) followed by warrant (Deduction)
		Student 3: (iii) is false. Force from the water is always opposite to the motion of the diver and will *decelerate* the diver.	(iii) Rebuttal followed by a claim followed by Warrant. (student 3) (Causality)
		Student 4: (adds further to student 3's argument): if the diver's body is not streamlined then the diver experiences air resistance that can slow her down. So even in water the wrong form can slow down the diver faster because of water resistance.	(Student 4): Adds backing to student 3's comment. (Causality)
		Student 5: (adds to student 3 and 4 comment): But because of gravity the diver will still move downward. The force from the water cannot be greater than the force of gravity.	(Student 5): adds further warrant to student 3 and 4 responses. (Causality)
		Student 6: (iv) is correct. Student 3 explained it.	Student 6: makes a claim.
		Student 7: (v) Momentum must be replaced by gravity. Gravity pulls the diver downward.	Student 7: Makes a claim and provides a warrant. (Causality)

Table 6

Analysis of Teacher Directed Dialogic Discussion in Physics (Class 9A) – Question 3

Teacher comment/question		**Student responses**	
Teacher comment verbatim	**ESRU factors (Elicits, Recognizes, Uses)**	**Student comment verbatim**	**TAP feature/s (epistemic operator)**
The teacher drops a ball as a demonstration to clarify the question. However, for this question the teacher is actively engaged in providing clarifications for student initiated questions and doubts.	The teacher Elicits student responses to • Interpret information • Formulate scientific explanations Uses student responses by • Promoting discussion among students' ideas and conceptions. • Promoting students' thinking by asking them to elaborate their responses (asks why? What?). **R**ecognizes student responses by • Clarifying and rephrasing student responses.	**Student 1**: Gravity pulls the ball down. As it falls its velocity increases, but decreases as the ball rises up.	Student 1: Claim and warrant. (Causality)
		Student 2: When ball hits ground Newton's third law applies.	Student 2: Claim
		Student 3: the ball hits the ground with a large force and therefore the ground hits the ball with the same large force. This force is greater than gravity and causes the ball to rise.	Student 3: Claim and warrant. (Causality/ deduction)
		Student 4: If we throw the ball at 10m/s then by action-reaction will the ball bounce back at 10m/s?	Student 4: Question
		Student 3: Ball experiences the frictional force on contact with the ground and loses energy. It does not rise back with the same speed.	Student 3: Warrant (Deduction)
Teacher (after student 3): Is it only the force of friction that causes the ball to lose speed and height?		**Student 5**: I think the smaller rebound height is due to the drag from the air.	Student 5: Claim
		Student 5: There is air resistance that causes energy loss and therefore loss of speed.	Student 5: warrant (Deduction/ Causality)
		Student 4: But if gravity speeds up the ball how can it rise up at 10m/s?	
Teacher: Gravitational force during free fall and reaction from the ground when the ball makes contact.		**Student 4**: So finally is it gravitational force or frictional force to describe the motion of the ball?	Student 4: another question

Overall during dialogic discourse for class 9A, argumentation was woven into instruction of new material for biology and chemistry. No new material was taught during the physics class, but argumentation helped to reinforce understanding of Newtonian principles when they were applied to unfamiliar situation.

Biology 9B science classroom discourse. In section 9B biology, the teacher started class on Wednesday by reviewing plant and animal cells—a topic the students had studied earlier. Then the teacher used a power point presentation to disseminate information about different kinds of epithelial tissues. During instruction, she asked a few questions that tested students' understanding of the material (see Figure 17). Answers provided by students to the teacher's questions allowed for dialogic discourse (DD) and is analyzed in Table 7. Friday's class was discussion-based as students applied their knowledge of epithelial tissues to identify where these could be found in various organs of the human body. Table 7 also shows analysis of the teacher-directed dialogic discourse for Friday's class. Questions raised by the teacher are included in the analysis of dialogic discourse to place students' responses in context. The first student to answer each question is identified as Student 1. However, this does not mean that every Student 1 represents the same individual. The number of respondents in the biology class is indicative of the high level of student engagement during teacher-directed dialogic discourse.

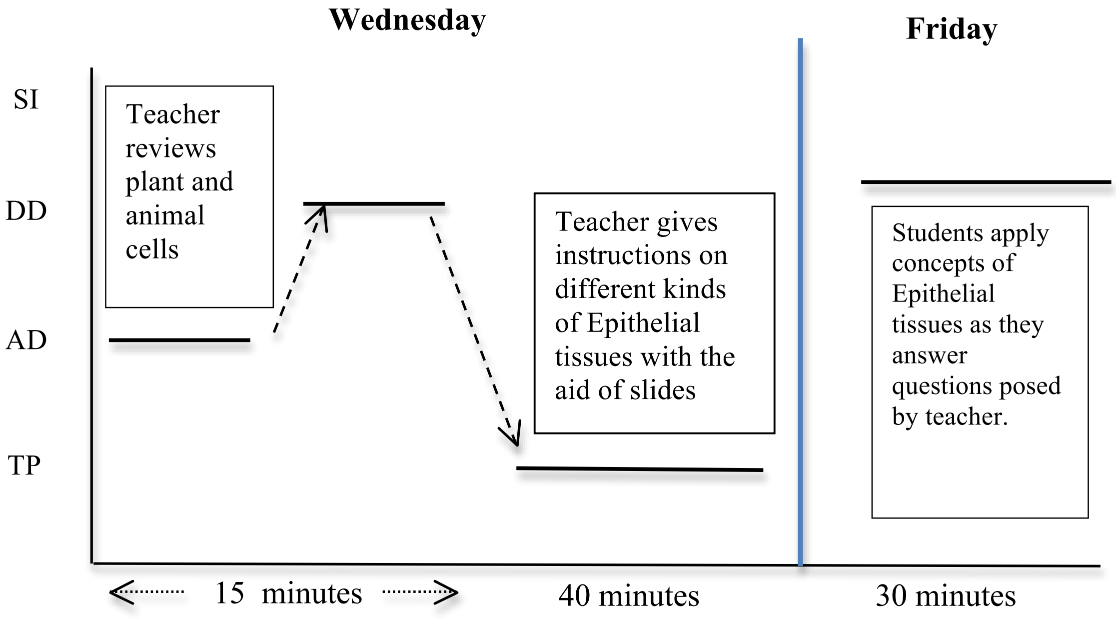


Figure 17. Classroom Discourse Map: 9B Biology

Table 7

Analysis of Teacher Directed Dialogic Discussion in Biology (Class 9B)

Teacher comment/question		**Student responses**	
Teacher comment verbatim	**ESRU factors (Elicits, Recognizes, Uses)**	**Student comment verbatim**	**TAP feature/s (epistemic operator)**
WEDNESDAY: **Question 1:** **Can you differentiate between plant tissue and animal tissue.** **Teacher** (after student 1): Stationary? Do you mean that plant tissues are rigid and animal tissues are flexible and therefore locomotive? Any other difference?	The teacher: Elicits student responses by asking for comparisons of concepts, Recognizes student responses by re-voicing students' words The teacher: Elicits student responses by asking	**Answer 1:** **Student 1**: Plant tissues are stationary but animal tissues are not. **Student 2**: Plant tissue has dead tissues made of scalecima while there is no dead tissue in animal cell.	Student 1: Claim Student 2: Warrant (Appeal to attribute)

Teacher comment/question		**Student responses**	
Teacher comment verbatim	**ESRU factors (Elicits, Recognizes, Uses)**	**Student comment verbatim**	**TAP feature/s (epistemic operator)**
Question 2: **Why do you think the chest cavity changes in volume as we breathe?**	them to apply and relate concepts **U**ses responses by asking students to elaborate	**Answer 2:** **Student 1**: The lungs inflate and collapse.	Student 1: Claim
Teacher (after student 3) : so?	**R**ecognizes by paraphrasing student contributions.	Teacher: elaborate **Student 2**: they fill with air	Student 2: Claim
		Student 3: the diaphragm muscles relax and increase the volume of the chest.	Student 3: Warrant (Causality)
Teacher: Correct! During exhalation the diaphragm regains its shape and pushes the air out.		**Student 4**: This decreases the pressure of air in the lungs and so air from outside rushes in.	Student 4: Backing (Deduction)
Question 3: **During breathing we take in oxygen. Where does the oxygen go?**	Teacher **U**ses student responses to promote their thinking by asking them follow up questions.	**Answer 3:** **Student 1**: It enters our blood thorough the lungs	Student 1: Claim
Teacher (after student 1): what is blood?		**Student 1**: it is a fluid that flows.	Student 1: Claim
Teacher (after student 1 next reply): what else?	**R**ecognizes student responses by rephrasing their answers.	**Student 2**: It transports	Student 2: Claim
Teacher: Blood is a tissue. Muscles are also tissues. Today we will discuss Epithelial tissues. Teacher uses question 3 to form the basis for instruction on Epithelial tissues.			
FRIDAY: **Question 1: Identify parts of the body where ciliated columnar epithelial tissues are present?**	Teacher **E**licits student responses to check students' comprehension ; **R**ecognizes student responses by summarizing students' words, and allows for active student participation as they build on each others' answers	**Answer1:** **Student 1:** in the respiratory tract as they help to move food particles.	Student 1: Claim and Warrant (Consistency with knowledge)
Teacher: Correct. The celia trap the dust particles and prevent it from entering our lungs.		**Student 2**: But the food moves down the esophagus which has Squamous epithelial tissues. Besides, food moves down the	Student 2: Rebuttal

Teacher comment/question		Student responses	
Teacher comment verbatim	**ESRU factors (Elicits, Recognizes, Uses)**	**Student comment verbatim**	**TAP feature/s (epistemic operator)**
		esophagus by muscular contraction.	
Teacher: Correct. The ciliated epithelial tissues have two functions.		**Student 1**: yes, but if small pieces of food enter the respiratory track or dust particles enter then the cilia help to move them out by trapping them in the mucus layer	Student 1: Backing (Causality – looking for mechanisms)
Question 2: **What is the difference between Cuboidal epithelial tissue and Glandular epithelial tissues?**	Teacher **E**licits student responses by asking them to compare and contrast; Recognizes students' answers by asking follow up questions and allowing student initiated questions; **U**ses student input by promoting students' ideas.	**Student 3**: the fallopian tubes also contain ciliated columnar tissues to move the ova.	Student 3: Claim and Warrant (Induction)
		Student 4: so the ciliated tissues can help to trap particles in the respiratory system and to move ova in the reproductory system?	Student 4: Question
Teachcr: Correct. Where can we find these in the human body		**Answer 2:** **Student 1:** Cuboidal tissues support the mechanical structure of an organ while the glandular tissues secrete hormones or enzymes.	Student 1: Claim
Teacher: Good question student 4. Any responses?		**Student 2**: Glandular tissues in the glands like pancreas to secrete insulin.	Student 2: Claim
	Teacher **U**ses students ideas by helping make connections with previous learning Teacher also corrects wrong reasoning used by student 6.	**Student 3**: Cuboidal in the kidney, and on the surface of various organs.	Student 3: Claim
		Student 4: Can an organ have both cuboidal and glandular tissues?	Student 4: Question
		Student 3: Yes. Sweat glands can have cuboidal tissues to protect the gland from injury, but glandular tissue to help secrete sweat.	Student 3: Claim and Warrant (Deduction)
Teacher: In chemistry you have studied evaporation. In summer the warm temperatures cause water to evaporate from the body surface – sweating. Therefore we feel dehydrated and drink a lot of water.		**Student 5**: Why do we sweat more in summer or when we are nervous?	Student 5: Question
		Student 6: In summer we drink a lot of water because we feel dehydrated so we	Student 6: Warrant (Causality)

Teacher comment/question		Student responses	
Teacher comment verbatim	**ESRU factors (Elicits, Recognizes, Uses)**	**Student comment verbatim**	**TAP feature/s (epistemic operator)**
		sweat more.	
Question 3: **What kinds of epithelial tissues can exist in the alimentary canal?**	The open-ended question Elicits responses that encourage students to apply knowledge; and to engage in a discussion that promotes exploration of ideas.	**Answer 3:** The class breaks into an animated discussion about the possible epithelial cells based on the function of the alimentary canal – digestion starting from the mouth, absorption of nutrients, secretion of enzymes, protection of lining of canal. The teacher lets the chatter flow for the last 5-7 minutes of class till the bell goes.	Cannot be deciphered.

During dialogic discourse in section 9B biology, the teacher generally follows the sequence of eliciting (initial question) and recognizing (by paraphrasing) student responses. Occasionally, the teacher uses student responses by asking for more clarification or by connecting their response to previous knowledge. Student responses are mostly claims and their justifications appeal to consistency with knowledge or deduction (epistemic operators).

Chemistry 9B science classroom discourse. For chemistry in section 9B, the class was divided into groups and each group was assigned a workstation that had an apparatus for separation of mixtures. The teacher went to each workstation to demonstrate for the group how to use the apparatus to collect data. During the demonstration, the teacher asked questions that helped students focus on manipulating the apparatus for reliable data. Students then worked in groups to practice a separation technique (Figure 18). The question-answer dynamics during teacher demonstrations is analyzed as dialogic discourse in Table 8.

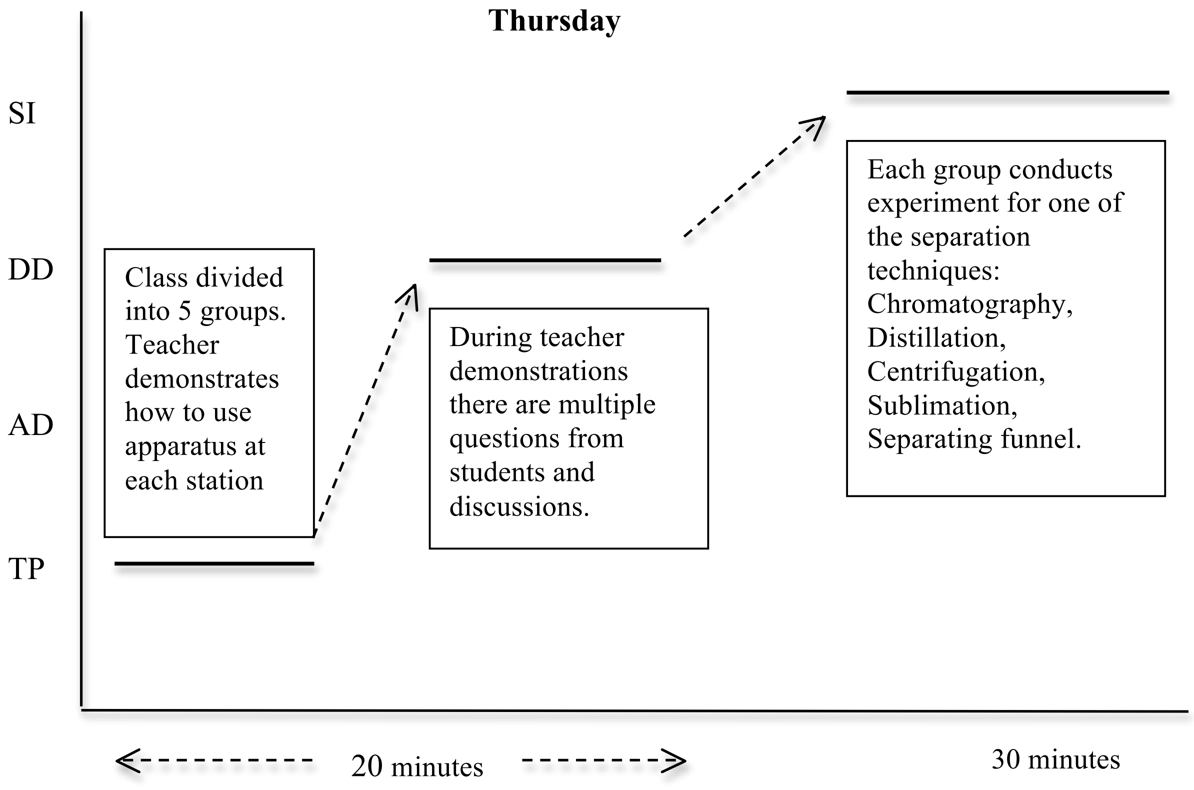


Figure 18. Classroom Discourse Map: 9B Chemistry

Table 8

Analysis of Teacher Directed Dialogic Discussion in Chemistry (Class 9B)

Teacher Comments/questions		**Student responses**	
Teacher comment Verbatim	**ESRU factors (Elicits, Student Responds, Recognizes, Uses)**	**Student comment Verbatim**	**TAP features/ Epistemic Operators**
Chromatography:	Teacher Creates a space for students to discuss	**Student 1**: Why are the colors not separating at	Student 1: Question

Teacher Comments/questions		**Student responses**	
Teacher comment Verbatim	**ESRU factors (Elicits, Student Responds, Recognizes, Uses)**	**Student comment Verbatim**	**TAP features/ Epistemic Operators**
	(**R**ecognizes)	the same rate?	
		Student 2: Probably because different colors have different solubility in water.	Student 2: Warrant and Backing (Classifying)
		Student 1: The more soluble color rises faster?	Student 1: Question
Teacher: If I used another solvent would the rate of rise of each color be the same?	Teacher **E**licits student responses by inviting predictions.	**Student 3**: yes.	Student 3: Claim
		Student 1: I think no, because the solubility will change with the solvent.	Student 1: Claim and warrant (Causality)
	Teacher Creates a space for students to discuss (**R**ecognizes)		
Separating Funnel:			
		Student 1: why is the liquid floating over water?	Student 1: Question
	Teacher **U**ses student 3 response by promoting discussion and consider alternative explanation.	**Student 2**: because it is less dense than water.	Student 2: Backing (Causality-prediction)
		Student 1: why are we allowing the water to drain drop by drop?	
Teacher: Do you agree with student 3? Is his reasoning correct?		**Student 3**: Otherwise the layers of liquid will be disturbed and oil will flow out before all water is drained.	Student 3: Claim and Warrant (Causality – mechanism)
	Teacher **R**ecognizes student response by rewording their contribution.	**Student 2**: I think if the water is allowed to flow fast then we may miss the opportunity to turn off the valve when all the water has drained but I don't think oil can flow out before water because it is less dense than water.	Student 2: Counter claim and Warrant (Appealing to attribute of density)
Teacher: Correct! The drop by drop flow of water is to ensure that we can close the valve at the right time.		**Student 4**: Can this	Student 4: Question

Teacher Comments/questions		**Student responses**	
Teacher comment Verbatim	**ESRU factors (Elicits, Student Responds, Recognizes, Uses)**	**Student comment Verbatim**	**TAP features/ Epistemic Operators**
		method be used to separate liquids whose density is very close?	
	Teacher **E**licits student responses by asking for scientific explanations	**Student 5**: I think we can but it will be difficult to see the separate layers.	Student 5: Claim and Warrant (Causality – prediction))
		Student 4: what about more than two immiscible liquids?	Student 4: Question
Sublimation: Teacher: Why did we not use filtration before sublimation in order to separate the mixture of salt, sand, and ammonium chloride?	Teacher **U**ses student responses by inviting alternate explanation. Teacher **R**ecognizes and **U**ses student responses by elaborating further their contribution.	**Student 6**: yes, as long as the liquids separate out into different layers we can use this method of separation.	Student 6: Claim and Warrant (Causality – prediction)
Teacher: Is there another possible explanation?		**Student 1**: Because we would lose some salt and ammonium chloride through filtration.	Student 1: Claim and Warrant ((Appeal to attribute)
Teacher: Also, if a solution is first formed then both salt and ammonium chloride will dissolve in water and it is difficult to sublime ammonium chloride in solution. It is best to separate ammonium chloride, then filter the solution of sand and salt, and finally to get salt from evaporation.	Teacher **E**licits student responses by inviting scientific explanation. Teacher **E**licits student responses by inviting predictions.	**Student 2:** salt and sand don't sublimate. So separating out ammonium chloride first before dissolving in water is helpful	Student 2: Warrant and Backing (Appeal to Attribute)
Condensation: Teacher: Why did I collect pure water through condensation and not through evaporation or			

Teacher Comments/questions		Student responses	
Teacher comment Verbatim	**ESRU factors (Elicits, Student Responds, Recognizes, Uses)**	**Student comment Verbatim**	**TAP features/ Epistemic Operators**
separating out the soluble salt by crystallization? Teacher: What should be the minimum difference in boiling points in order to separate the liquids by condensation?		**Student 1**: Condensation is a process used to separate two miscible liquids with different boiling points. (Teacher affirms)	Student 1: Claim, Warrant, and Backing. (Definition)
		Student 2: at least 25-30 degrees centigrade. Because impurities can change the boiling point slightly it is better to have a larger difference, otherwise the liquids can evaporate together.	Student 2: Claim, Warrant, and Backing.(Deduction)

Student questions: "why are the colors not separating at the same rate?", "why is the liquid floating over water?", "Can this method be used to separate liquids whose density is very close?", and "what about more than two immiscible liquids?" in addition to the teacher's follow up questions to student responses: "Is there another possible explanation?" and "do you agree with student 3? Is his reasoning correct?" alert the students to the connection between properties of matter in a mixture and the separation technique used. Students' responses reflect cognitive reasoning that predominantly draw on epistemic operators of causality – prediction, and appeal to attribute. As the teacher uses student responses by inviting alternate explanation and by elaborating on student responses, she enriches the learning experience for students.

Physics 9B science classroom discourse. On Monday, the physics teacher for section 9B provided formal instruction on Newton's Laws of motion. Although the teacher asked questions during instruction to engage students in the lesson, the class is identified as a teacher presentation (TP). On Tuesday, the class was divided into six groups. Each group attempted a question on the worksheet and then discussed their answers with the class. The 30 minutes during which individual groups are engaged with the entire class as they justify their responses and rebut others' responses they disagree with, is analyzed in Tables 9, 10, and 11 (for questions 1, 2, and 3 respectively – Appendix I) as teacher directed dialogic discourse.

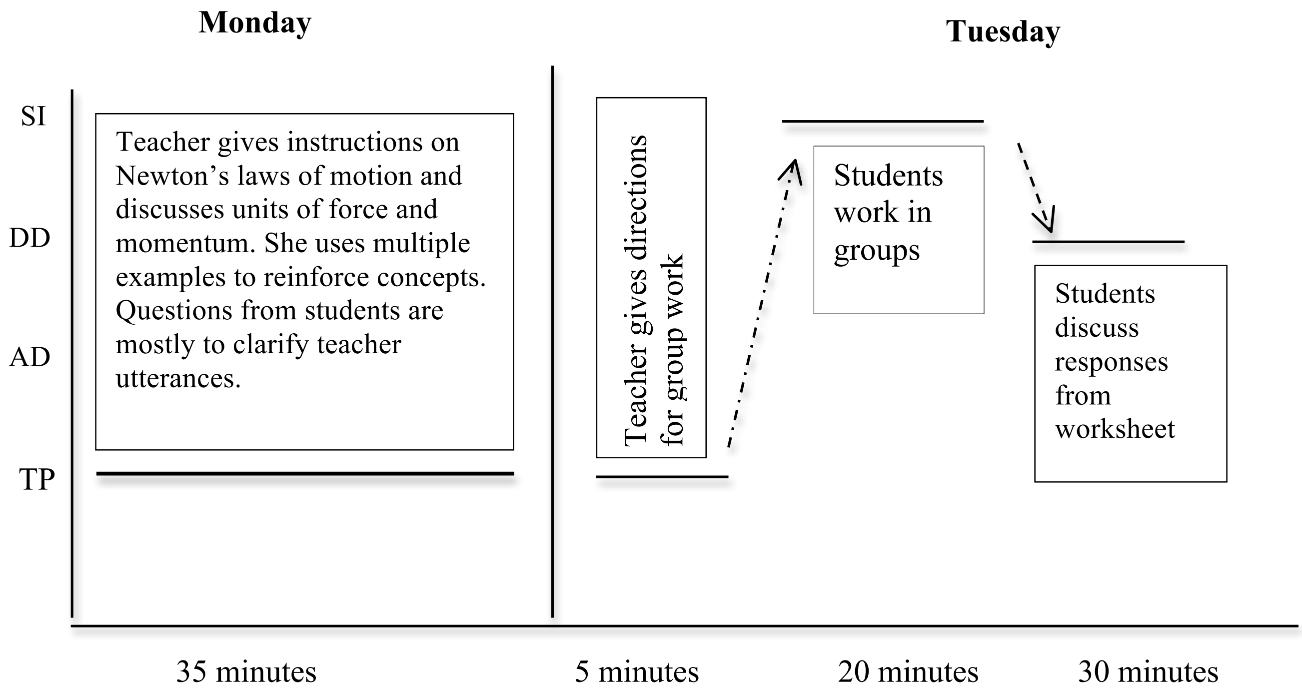


Figure 19. Classroom Discourse Map: 9B Physics

Table 9

Analysis of Teacher Directed Dialogic Discussion in Physics (Class 9B) – Question 1

Teacher Comments/questions		**Student responses**	
Teacher comment Verbatim	**ESRU factors (Elicits, Student Responds, Recognizes, Uses)**	**Students comment Verbatim**	**TAP features/ Epistemic Operators**
TUESDAY **Teacher:** To student 3 – do you agree with students1 and 2? **Teacher** prompts student 3 by asking more questions: As the diver jumps what	Teacher **E**licits student responses to check their comprehension and to formulate scientific explanation. **Teacher** promotes thinking by providing ques and asking clarifying questions.	**Student 1**: The diver does not fall parallel because the force of gravity acts downwards. **Student 2**: Gravity pulls downwards and prevents the diver from moving straight **Student 3**: unable to answer	Student 1: Claim, Warrant, and Backing (Causality) Student 2: Claim and Warrant (Causality) Student 3:

Teacher Comments/questions		Student responses	
Teacher comment Verbatim	**ESRU factors (Elicits, Student Responds, Recognizes, Uses)**	**Students comment Verbatim**	**TAP features/ Epistemic Operators**
force acts on him? Teacher: so how does gravity change motion? **Teacher:** Correct. Gravity pulls the diver downwards, perpendicular to the direction of jump.	**R**ecognizes student responses by elaborating on their answers.	**Student 3**: gravity **Student 3**: pulls it downwards and therefore prevents horizontal motion.	Student 3: Claim Student 3: Warrant (Causality)
(ii) **Teacher** (following student 3): when you dive towards water the acceleration is approximately 9.8 m/s2 but after hitting the water is the acceleration same as g?	Teacher **R**ecognizes student's question and provides guiding questions to help arrive at answer.	(ii) **Student 1**: equal and opposite forces between diver and water. **Student 2**: the answer is correct as the water slows down the diver faster than he falls. **Student 3**: does the water pull the diver downward? **Student 2**: no, gravity is downward and water force is upward. **Student 2**: the buoyant force and resistance from water act on the diver and so his acceleration is less than 9.8 Hence the diver slows down faster.	Student 1: Claim and Warrant (Deduction) Student 2: Claim and Warrant (Causality) Student 3: Question Student 2: Claim and Warrant (Causality) Student 2: Claim, Warrant, and Backing (Deduction)
(iii) **Teacher (after student 1):** what else? **Teacher (after student 2):** Correct,	Teacher **R**ecognizes student responses by paraphrasing their contribution.	(iii) **Student1**: False because the diver will decelerate no	Student 1: Claim and Warrant

Teacher Comments/questions		**Student responses**	
Teacher comment Verbatim	**ESRU factors (Elicits, Student Responds, Recognizes, Uses)**	**Students comment Verbatim**	**TAP features/ Epistemic Operators**
the right form saved the diver from injury and allows for smooth motion into water but the upward forces will slow down the diver.		matter what her form.	(Deduction)
		Student 2: but the diver must be streamlined to avoid injury.	Student 2: Warrant (Appeal to attribute)
(iv)		**Student 1**: so the diver can cut through water.	Student 1: Warrant (Deduction)
	Teacher **R**ecognizes student 2 question and **E**licits response from the class. Teacher **R**ecognizes student responses by incorporating their contribution in her summary.	(iv)	
		Student 1: Correct as the water provides an opposing force.	Student 1: Claim and Warrant (Causality)
(v)		(v)	
		Student 1: Gravity pulls the diver downward but his horizontal speed may make him travel horizontally.	Student 1: Claim and Warrant ((Consistency with other knowledge)
Teacher: Good question. Any responses to student 2?		**Student 2**: does the diver have horizontal momentum?	Student 2: Question
Teacher: Gravity changes momentum in the vertical direction and keeps the diver's motion in the vertical direction.		**Student 1**: yes there is horizontal momentum but this momentum stays constant.	Student 1: Claim and Warrant. (Deduction)
		Student 4: and vertical momentum increases so the motion of the divers is vertical.	Student 4: Claim and Warrant (Deduction)

Table 10

Analysis of Teacher Directed Dialogic Discussion in Physics (Class 9B) – Question 2

Teacher Comments/questions		**Student responses**	
Teacher comment Verbatim	**ESRU factors (Elicits, Student Responds, Recognizes, Uses)**	**Student comment Verbatim**	**TAP features/ Epistemic Operators**
TUESDAY **Justify your choices.**	Teacher **E**licits student responses and creates a space for student discussion (Uses) and exploration of idea.	**Student 1**: I think B is correct because the mass of the car is greater than the insect's and so the car exerts a greater force.	Student 1: Claim and Warrant (Deduction)
		Student 2: also since the car is moving it exerts a greater force	Student 2: Warrant (Causality)
Teacher: Student 5 is correct. Since force is proportional to the rate of change of momentum the change in momentum is also the same. The lighter mass has a larger change in speed compared to the heavier mass. So the insect's change in velocity is larger but its change in momentum is the same as the change in momentum of the car.	Teacher **R**ecognizes student response by re-voicing contribution and Uses contributions by providing descriptive feedback.	**Student 3**: I think A is correct because if the insect experiences a greater force from the car then by Newton's law its change in momentum is greater as well.	Student 3: Claim, Warrant, and Backing.(Deduction)
		Student 4: But momentum is a vector. So car also experiences a change in momentum.	Student 4: Warrant (Deduction)
		Student 5: I think C is correct according to Newton's third law of action and reaction. Force exerted by the car on the insect is the same as the force exerted by the insect on the car.	Student 5: Claim, Warrant, and Backing. (Deduction)
		Student 3: does mass have any effect? Nobody answers.	Student 3: Question.

Table 11

Analysis of Teacher Directed Dialogic Discussion in Physics (Class 9B) – Question 3

Teacher Comments/questions		**Student responses**	
Write the comment Verbatim	**ESRU factors (Elicits, Student Responds, Recognizes, Uses)**	**Write the comment Verbatim**	**TAP features/ Epistemic Operators**
TUESDAY **Teacher:** what force acts on the ball at its highest point?	Teacher Elicits student responses by inviting predictions.	**Student 1**: there are three forces – gravity, air resistance, and friction with the ground.	Student 1: Claim and Warrant (Consistency with knowledge)
Teacher: Is friction important when the ball hits the ground?	Teacher Uses student response by promoting their thinking through follow-up questions.	**Student 2**: There is also the normal force from the ground when the ball touches it.	Student 2: Warrant (Consistency with knowledge)
	Teacher Uses student response by promoting their thinking through follow-up questions.	**Student 3**: at the highest point the force of gravity is the only force. **Student 1**: why not air resistance?	Student 3: Claim Student 1: Question
Teacher: Correct, there is no friction with the ground although you can consider air to offer a small resistive force.		**Student 3**: air resistance depends on speed. At the highest point the ball stops and therefore there is no air resistance.	Student 3: Claim, Warrant, and Backing (Deduction)
I want all of you to think about whether the normal force is larger than, equal to, or less than the force of gravity on the ball. We will discuss in the next class.	Teacher Recognizes student responses in paraphrasing their contribution Uses student response by promoting their thinking through follow-up questions.	**Student 1**: yes **Student 4**: But ball is not moving on the ground so friction is not important. **Student 2**: Can normal force be friction? **Student 1**: I change my initial answer. There is no friction with the ground There is normal force that pushes the ball back up but because the ball does not slide on the ground there is no friction.	Student 1: agrees Student 4: Counter claim and Warrant (Deduction) Student 2: Question Student 1: Counter claim, Warrant, and Backing. Deduction)

During the physics class for section 9B, students experienced encouragement from the teacher to think creatively, especially as the teacher provided prompts and guiding questions to help students consider alternate approaches to arriving at answers. Deductive reasoning and causality were the predominant cognitive arguments (epistemic operators) used by students during their responses.

Classroom discourse in class 9B overall was more substantive than the discourse in class 9A. For example, for the same physics worksheet, students in class 9B alluded to buoyant force from water, dependence of air resistance on the speed of a moving object, and discussed why frictional losses between ground and ball are insignificant for a bouncing ball—ideas that students in 9A physics class did not discuss. This difference between sections could probably be due to the fact that the physics teacher of class 9B asked many more follow-up questions (uses) to student responses as compared to the physics teacher of class 9A, who paraphrased and re-worded (recognized) student responses with greater frequency.

Biology 9C science classroom discourse. For section 9C biology, Tuesday's class was devoted to providing information on cells and tissues. Occasionally the teacher directed questions that elicited brief responses from students, but the events in the class were predominantly teacher presentation (TP) and teacher-directed authoritative dialogue (AD). On Thursday, students applied their understanding of the structure and function of various epithelial tissues as they attempted to answer questions on a worksheet (Figure 20). Students worked independently on the worksheet for the initial 15 minutes and then engaged in dialogue. Thursday's lesson is analyzed for teacher directed dialogic discussion in Table 12.

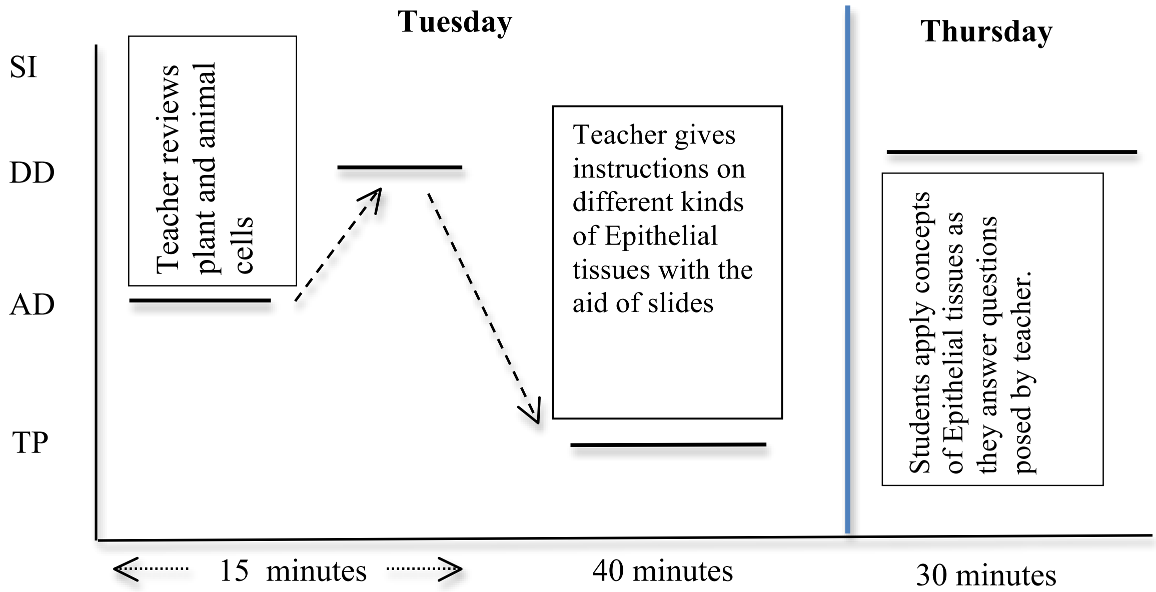


Figure 20. Classroom Discourse Map – 9C Biology

Table 12

Analysis of Teacher Directed Dialogic Discussion in Biology (Class 9C)

Teacher comment/question (Biology – Thursday)		**Student responses**	
Teacher comment verbatim	**ESRU factors (Elicits, Recognizes, Uses)**	**Student comment verbatim**	**TAP feature/s (epistemic operator)**
		Question 1: diagram of human anatomy with some parts identified for nature of epithelial cells.	
	Teacher Elicits student responses	**Student1**: Air sacs of lungs contain squamous epithelial tissues because they allow exchange of gases.	Student 1: Claim and Warrant (Classifying)

Teacher comment/question (Biology – Thursday)		**Student responses**	
Teacher comment verbatim	**ESRU factors (Elicits, Recognizes, Uses)**	**Student comment verbatim**	**TAP feature/s (epistemic operator)**
Teacher: but facilitating gas exchange is the function of the alveoli. **Teacher:** how is diffusion facilitated?	Teacher Uses student responses by asking follow-up questions that promote thinking and encourage students to support their answers.	**Student 2**: Yes, but squamous tissues have single layer of cells which makes it easier for gases to diffuse.	Student 2: Agrees and Backing (Consistency with knowledge)
		Student 3: the difference in concentration of gases on either side of the cell wall allows flow to equalize concentration. This is diffusion.	Student 3: Claim, Warrant, and Backing. (Deduction & Definition)
		Student 4: Respiratory track has ciliated epithelial cells so that the cilia along with the mucus can trap foreign particles and eject them out of the nose.	Student 4: Warrant and Backing. (Causality)
		Student 5: by sneezing? (the class laughs)	Student 5: Question
Teacher: the nose also contains columnar epithelial cells and provide sensory function. The oral pharynx contains the cuboidal epithelium which protects the inner lining during swallowing.	Teacher **R**ecognizes student responses by including their contribution in her feedback.		
Teacher: Good reasoning.	Teacher Uses student responses to encourage thinking and discussion in class.	**Student 5**: The intestines contain the simple columnar epithelial tissue as they have to absorb nutrients.	Student 5: Claim and Warrant. (Causality)
		Student 6: The kidneys contain cuboidal epithelial cells as they have to allow secretion of fluids.	Student 6: Claim and Warrant (Appealing to attribute) Student 7: Claim and Warrant (Consistency with

Teacher comment/question (Biology – Thursday)		**Student responses**	
Teacher comment verbatim	**ESRU factors (Elicits, Recognizes, Uses)**	**Student comment verbatim**	**TAP feature/s (epistemic operator)**
		Student 7: The kidney has exocrine glands. the base of cuboidal cells forms ducts that allows chemicals to move to urethra.	knowledge)
Teacher: student 7 has mentioned exocrine glands whose major function is to store secretions. But the role of the kidney is to purify. So think, what is the role of the cuboidal tissue in the kidney?			Student 8: Claim.
		Student 8: the adrenaline is an endocrine gland that secretes adrenaline.	
			Student 7: Question
	Teacher **R**ecognizes student responses by summarizing their contribution to the conversation.	**Student 7**: So the ducts at the bottom of the cuboidal tissue keep the impurities?	Student 7: Question
		Student 7: so the bottom of the cuboidal tissue stores blood?	
Teacher: Well the filters in the kidney are made of cuboidal epithelial in order to trap impurities.			Student 7: Question
		Student 7: so where is blood stored?	
Teacher: ducts are at the bottom of the endocrine glands.			
Teacher explains the function of the cuboidal tissue as ion exchange of salts between blood and urinary			

Teacher comment/question (Biology – Thursday)		Student responses	
Teacher comment verbatim	**ESRU factors (Elicits, Recognizes, Uses)**	**Student comment verbatim**	**TAP feature/s (epistemic operator)**
track. **Teacher**: blood flows through the body within the circulatory system.			

During the conversations in biology 9C, the teacher actively used and recognized student responses. Students used cognitive reasoning (epistemic operators) that appealed to attributes of cells and tissues, and represented consistency with knowledge. Their responses also demonstrated their cognitive skill to classify, define, and deduce from evidence properties of tissues in organs. TAPping during argumentation included warrants and backing. Student initiated questions were prompted by the desire to clear gaps in understanding. For example: "…so the bottom of cuboidal tissue keeps the impurities? Stores blood?"

Chemistry 9C science classroom discourse. During the one-on-one interview the teacher for Chemistry 9C did not identify the topic – Concepts of Matter Around Us – as a unit for instruction. Wednesday's class time was spent on independent work on worksheets and Friday's class time was spent working on building models of matter (elements, mixtures, and compounds) in small groups (Figure 21). On Wednesday, there was one question from a student and the teacher allowed other students to respond to the question. Hence, although the interaction can be classified as student initiation (SI), since the responses from other students contained elements of TAPping, I have analyzed the brief conversation in Table 13.

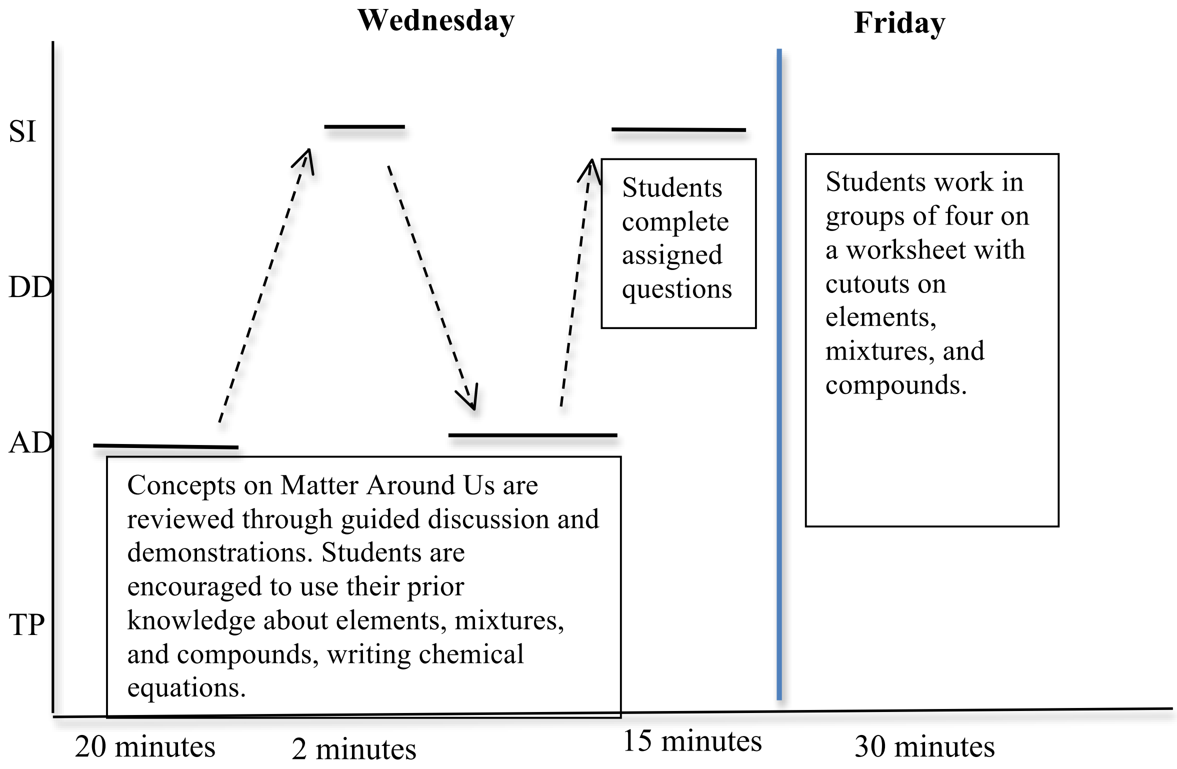


Figure 21. Classroom Discourse Map – 9C Chemistry

Table 13

Analysis of Teacher Directed Dialogic Discussion in Chemistry (Class 9C)

Teacher comment/question		**Student responses**	
Teacher comment verbatim	**ESRU factors**	**Student comment verbatim**	**TAP feature/s (epistemic operator)**
(Chemistry – Wednesday) **Good response to a good question.**	Teacher **R**ecognizes student question and creates space for student conversation.	**Student Question:** Distilled water has no dissolved salts but tap water has some dissolved substances. Is distilled water a compound and tap water a mixture?	
		Answer from student 1: Water is a compound. But tap water may be considered as a solution.	Student 1: Claim, Warrant, and Backing (Consistency with knowledge)
		Student 2: Solutions can be homogenous mixtures or heterogeneous mixtures.	Student 2: Warrant (Consistency with knowledge)

In Chemistry 9C, the teacher recognized the student's question and created space for student conversation. Student reasoning appealed to consistency of knowledge as they used properties of mixtures and compounds to support their answers. This class provided an example of substantive work and learning even in the absence of argumentation.

Physics 9C science classroom discourse. The 9C physics class met only on Monday (Figure 22). In this physics class, students were engaged in exploratory talk as they brought their real life experiences to make sense of Newtonian forces. The teacher conducted a series of demonstrations and invited students to provide explanations for the behavior of matter they observed. Student responses were generally a restatement of the law or limited to brief phrases as answers. When the teacher provided an explanation, students nodded in agreement with the teacher except for a brief period when a few students asked clarifying questions and their classmates contributed to the dialogue.

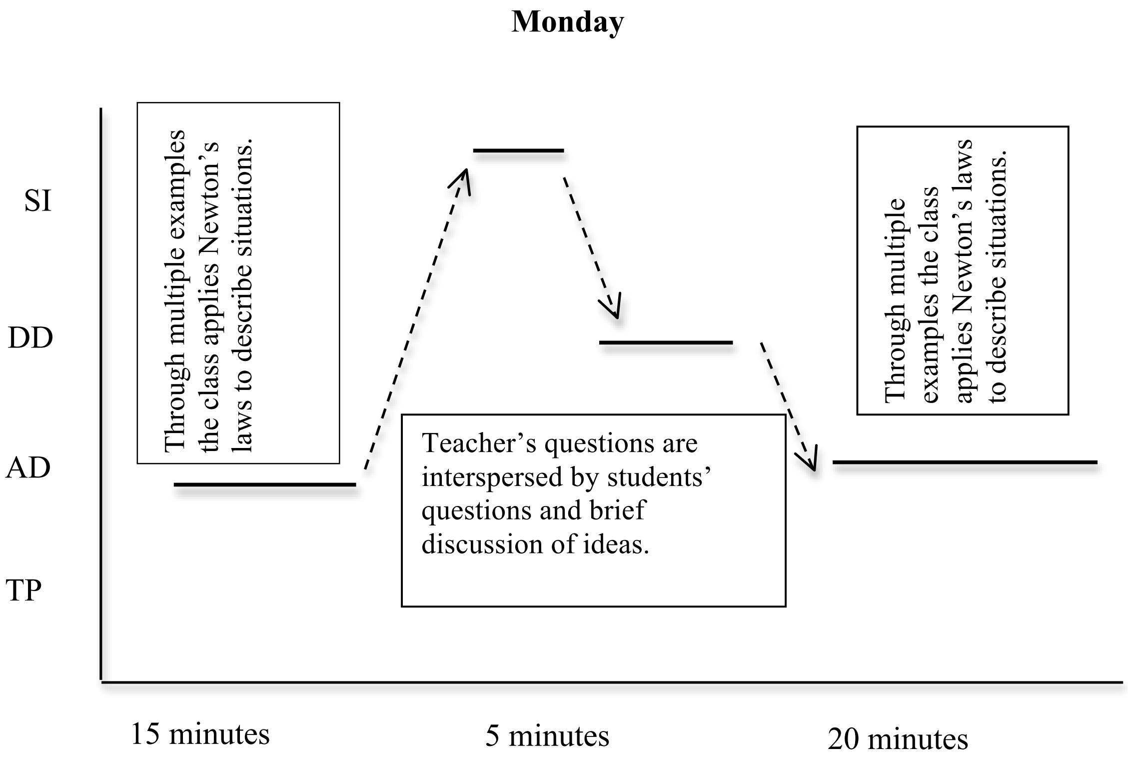


Figure 22. Classroom Discourse Map – 9C Physics

Analysis (see Table 14) of the brief conversation arising from teacher's demonstration shows that the teacher promoted debating among students who drew on causality – looking for mechanism, and deductive reasoning as they processed information to arrive at a collective understanding of inertia.

Table 14

Analysis of Teacher Directed Dialogic Discussion in Physics (Class 9C)

Teacher comment/question (Physics – Monday)		**Student responses**	
Teacher comment verbatim	**ESRU factors (Elicits, Recognizes, Uses)**	**Student comment verbatim**	**TAP feature/s (epistemic operator)**
Teacher: Let's take an example. The teacher whirls a mass along a circular path and explains that since the ball is constantly changing direction there must be an unbalanced force acting on the mass. Teacher lets go of the string and the mass moves along a straight line. Teacher explains that since the force has vanished the mass no longer moves along a circle.	Teacher Acknowledges student question and **U**ses response from another student to clarify answer by a demonstration.	**Question from student 1:** Can inertia of motion also be considered as inertia of direction?	Student 1: Question
		Answer from another student 2: I think yes because to change direction of motion an unbalanced force is needed.	Student 2: Claim, Warrant, and Backing. (Causality – looking for mechanism)
	Teacher creates a space to allow for student discussion and promotes promotes exploration of students' own ideas. (**U**ses)	**Question from another student 1**: I have seen people fall backwards when they jump out of a moving bus. Why is that so?	Student 1: Question
		Answer from student 2: I think the person should fall forward as he is in a state of forward motion with the bus when he jumps out. He will fall backwards if he jumps into a moving bus not if he jumps out of a moving bus.	Student 2: Claim and Warrant (Deduction)
		Student 3: Probably friction pulls the person backwards.	Student 3: Claim
		Student 4: Was the person facing in the	Student 4: Question followed by Warrant

Teacher comment/question (Physics – Monday)		**Student responses**	
Teacher comment verbatim	**ESRU factors (<u>E</u>licits, <u>R</u>ecognizes, <u>U</u>ses)**	**Student comment verbatim**	**TAP feature/s (epistemic operator)**
Teacher: yes, objects try to maintain their state of motion unless an external force changes the state. So the person must fall in the direction of the bus' motion if he jumps out of a moving bus.	Teacher **<u>R</u>**ecognizes student responses by summarizing the discussion.	direction opposite to the motion of the bus when he jumped out? Then he fell on his back but still in the forward in the direction of the bus' motion. (Everybody in the class laughs)	(Deduction)

Teacher A taught physics to both 9A and 9C, but the ways the teacher taught the unit of Newton's laws in the two sections were very different. Probably it was the nature of the learners in 9C (they were easily distracted and asked more questions than the other two classes both in biology and physics) that shaped instructional strategy. Teacher A also taught chemistry to class 9C and instead of running the lab on separation of mixtures the teacher taught the unit of *Concepts of Matter Around Us.* I was informed later when I inquired why class 9C was ahead of the other two classes (9A and 9B) in biology and the class did not do the chemistry lab for *Separation of Mixtures*, that chemistry labs for class 9C were managed by teacher D who also taught biology to the class. Hence, class 9C students experienced argumentation mostly in their biology class, and minimally in their chemistry and physics classes during the week of the study.

Each of the sections 9A, 9B, and 9C experienced different levels of argumentation through the week. For the same worksheet, each section had a different dialogic discourse (example: physics worksheet in 9A (teacher A) and 9B (teacher C)). The same teacher conducted argumentation differently for different classes (example: Teacher A in 9A and 9C). Argumentation in each class depended on the topic (and discipline), the context (lab, worksheet, introduction of new material), and the readiness of the students (as gauged by the teacher) to engage in dialogue.

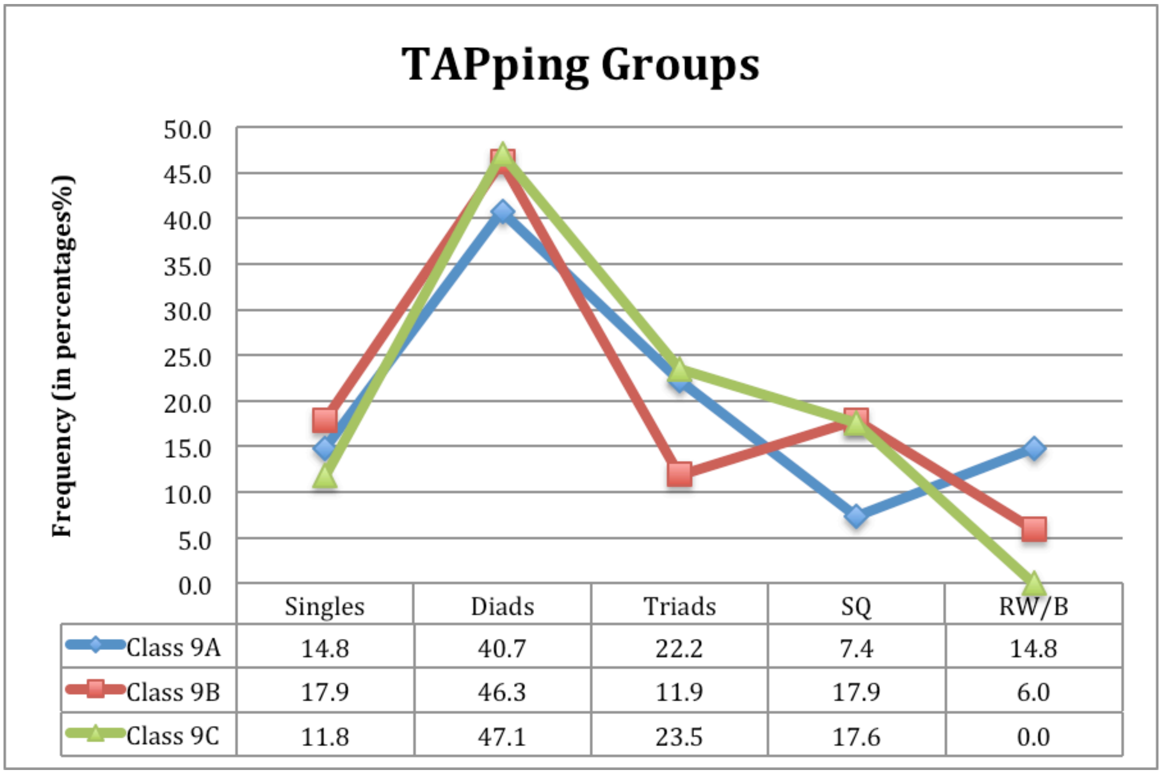
Quantifying TAPping for Each Grade Nine Section (9A, 9B, 9C). For the sake of looking at the argumentation landscape for the entire week, I have grouped TAP features for all sub-disciplines in each grade nine section (9A, 9B, 9C) for the week. TAP features are grouped into singles, dyads, and triads, to quantify their frequency of use within the science class (see Table 15). Singles represent claims made by students to a question by the teacher. Dyads include claim and warrant (CW), claim and backing (CB), and also instances when a student only provides a warrant or backing to another students' claim. Triads include a combination of claim, warrant, and backing. Although student questions (SQ) are not part of TAP they are indicative of thoughtful information processing by learners, which is essential for argumentation and therefore included in the quantification of TAP features. Additionally, rebuttals followed by a counter-claim and a backing or warrant have been given their own category (RCW) because they represent a higher order of information processing—evaluating another students' response within the context of one's own understanding of the information.

Table 15

TAP feature groups (in %) during Teacher Directed Dialogic (DD) Discussions

	Science Class Section			
	Class 9A	Class 9B	Class 9C	Average
Singles	14.8	17.9	11.8	14.8
Dyads	40.7	46.3	47.1	44.7
Triads	22.2	11.9	23.5	19.2
SQ	7.4	17.9	17.6	14.3
RW/B	14.8	6.0	0.0	6.9
Total	100	100	100	100

Figure 23 graphs the information from Table 15. It is apparent from this figure that dyads—generally a combination of a claim and an accompanying warrant or backing—were the most common TAP group. Student-directed questions were part of discussion as were instances with rebuttals where students disagreed with the existing answer and provided a justification for the rebuttal. Overall, the quality and quantity of TAP feature groupings were similar across all ninth grade cohort sections.



	Singles	Diads	Triads	SQ	RW/B
◆ Class 9A	14.8	40.7	22.2	7.4	14.8
■ Class 9B	17.9	46.3	11.9	17.9	6.0
▲ Class 9C	11.8	47.1	23.5	17.6	0.0

Figure 23. TAPping during Teacher Directed Dialogic Discussion (DD)

The format of argumentation in each sub-discipline was different. For example, the physics teachers used extensive question-answer format throughout their lesson, biology teachers transmitted pertinent knowledge and then followed up with questions that explored students' understanding, and chemistry instruction revolved around lab work—demonstrations by teacher and experimentation by the students. Hence learners in each science section experienced a variety of instructional contexts within which they practiced argumentation. In all situations, the conversation between students was not confrontational, but students were involved in exploratory talk that cumulatively built on each other's ideas for acquiring deeper understanding (Atwood, Turnbull, & Carpendale, 2010; Chappell, 2014; Mercer, 2008). While in exploratory talk, students are open to questions from their classmates, provide justifications for their responses and, like cumulative talk, build on each other's ideas; in cumulative talk, there is power sharing among learners, with the teacher facilitating the conversation. Additionally, the data from the current study show that although the teachers allowed for dialogue without interrupting the conversation to provide answers, the teachers were good at recognizing student responses and building off of students' comments to steer the conversation in the direction of goals of the lesson.

The nine examples of dialogic discourse above indicate an intuitive use by teachers of eliciting, recognizing and using student responses during instruction. The teachers' attempts to engage students seemed effortless as they asked follow-up questions to students or allowed for other students to build on their classmates' responses. It may be that since the teachers were experimenting with dialogic teaching, they were intentional about engaging students in classroom discourse. In other words, whereas teachers were skilled at facilitating argumentation, they were mindful also not to practice didactic approaches, but to create a space for dialogue in their classes. As all teachers stated in their interviews, teachers maintained control over the extent of time dialogue was allowed in class so that teachers could blend active learning through dialogic teaching with the demands of syllabus coverage.

Interestingly, another observation was that, for any question posed by a teacher, it generally took more than one student to provide the complete answer. For example, in Table 9, the teacher's question was, "Can you differentiate between plant tissue and animal tissue?" Student 1 responded, "Plant tissues are stationary but animal tissues are not." This answer in and of itself was not sufficient to answer the teacher's question. A second student stated, "Plant tissue has dead tissues made of scalecima while there is no dead tissue in animal cell."

Another observation was that students spontaneously provided scientific reasoning to support their responses, which suggested that while students were conditioned to integrate science principles in their answers, teachers' experiment with argumentation focused more on the process of inquiry learning and co-construction of knowledge rather than on developing scientific reasoning. Since I did not record or listen to the small group discussions before students shared their responses with the rest of the class, I am uncertain of the dynamics within the group of how students arrived at their group responses. Was there a consensus building process or did a group give into the answer of the stronger, more vocal student? And how did they decide to use one or two individuals as spokesperson for the group? This is also unknown. However, the conversation within groups was animated, and during whole-class dialogue, if the spokesperson was unable to give a response, others from the group would jump in. Overall, students appeared to enjoy the novel experience of being able to talk in class (with greater frequency) but using scientific reasoning, which was not a new skill for them. Also, by virtue of their training and educational degrees, teachers framed argumentation to ensure progression in learning (Berland & McNeil, 2011). The teaching-learning dynamics was clearly demonstrative of argumentative learning.

Quantitative Data: Change in Student Motivation

Since argumentation—at least to a degree—clearly occurred in these science classes and students responded receptively and with some enthusiasm, the question that remains is: *To what extent did student motivation in the science class change after students engaged in argumentation?*

The quantitative data used to answer this question was collected from students' responses on the Student Motivation Towards Science Learning (SMTSL) instrument. I imported the de-identified and matched data (pre and post participation in argumentation) from excel to SPSS and then analyzed the data in SPSS (Version 21). The cleaned data represented only those students who completed both the pre argumentation and the post argumentation survey. Sixty-seven of the 90 ninth graders completed both pre and post argumentation survey and thus formed my sample set.

I ran the normality test to check if the motivation survey data was distributed normally by gender and achievement level. The assumption of normality for motivation scores on the SMTSL instrument was not satisfied for all group combinations as assessed by Shapiro-Wilk's test ($p>0.05$). Consequently, I decided to use non-parametric tests (Table 18) to analyze the data. Additionally, non-parametric inferential statistical tests are available for analyzing the Likert-type scale-based ordinal score dependent variable (student motivation) in my study.

Table 16

Non-parametric equivalents for Parametric tests

Parametric Test	Non-parametric equivalent used for data analysis
Paired Sample *t*-test for entire group	Wilcoxon Signed Rank test
Independent sample *t*-test for difference in means pre and post argumentation by gender	Mann-Whitney U-test by gender
ANOVA on the variation of means of low, middle, and high achievers, pre and post argumentation	Mann-Whitney U-test by achievement

Student responses on the SMTSL instrument were analyzed using non-parametric tests as the sample did not meet the normality test for parametric statistical analysis. The following inferential statistical tests were undertaken:

Wilcoxon Signed Rank test for difference in mean (median) for the entire group. Wilcoxon Signed Rank test is a non-parametric equivalent of paired sample *t*-test. It helps to determine if there is a difference in scores of the dependent variable (motivation) in two related groups—pre and post engagement in argumentation in the science class.

The assumptions of this test include two design assumptions: (a) the dependent variable is continuous or ordinal and (b) the independent variable is categorical with two related groups. Data is paired and comes from the same population. The two sets of scores (pre and post argumentation) come from the same participants whose motivation was measured at two different times during the study. Sixty-seven of the 90 ninth grade students who completed both the pre and post argumentation survey were a random sample from the population. Additionally, selection of each participant within the population of ninth graders whose teachers were experimenting with argumentation was independent of selection of other participants for quantitative data. The third assumption deals with verifying whether the distribution of the differences between the two related groups is symmetrical in shape. These assumptions were met and the results of the test follow. The analysis of the survey instrument helped to understand the impact of argumentation in science classroom on student motivation.

Table 17

Wilcoxon Signed Ranks Test

Ranks				
		N	Mean Rank	Sum of Ranks
Postmean – Premean	Negative Ranks	38[a]	33.00	1254.00
	Positive Ranks	28[b]	34.18	957.00
	Ties	1[c]		
	Total	67		

Note: a. Postmean < Premean
b. Postmean > Premean
c. Postmean = Premean

Of the 67 participants in the study, motivation increased for 28, decreased for 38, and remained unchanged for one after engaging in argumentation in their science class (Table 17). A Wilcoxon signed-rank test determined that there was no statistically significant increase in motivation (-0.0693) post participation in argumentation (3.7633) compared to before participation in argumentation (3.7950), z = -0.949, *p* = 0.343 (see Table 18).

Table 18

Test Statistics[a] *Wilcoxon Signed Rank Test*

Z	-.949[b]
Asymp. Sig. (2-tailed)	.343

Note: a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

However, when the six motivation sub-scales (self-efficacy (SE), active learning strategy (ALS), science learning value (SLV), achievement goal (AG), performance goal (PG), and learning environment stimulation (LES)) on the SMTSL instrument were isolated, the Wilcoxon signed-rank test determined that there was a statistically significant decrease in student SE (-0.0693) post participation in argumentation (3.5714) compared to before participation in argumentation (3.7143), z = -3.706, *p* = 0.000, and a statistically significant increase in students' ALS (0.1250) post participation in argumentation (4.1250) compared to before participation in argumentation (4.0000), z = -2.764, *p* = 0.007 (see Tables 19 & 20).

Table 19

Test Statistics: Wilcoxon Signed Rank Test by Motivation Subscale

	Postmean - Premean	Post_SE - Pre_SE	Post_ALS - Pre_ALS	Post_SLV - Pre_SLV	Post_PG - Pre_AvgPG	Post_AG - Pre_AG	Post_LES - Pre_LES
Z	-.949[b]	-3.706[b]	-2.674[c]	-.996[b]	-.829[c]	-.169[b]	-.445[b]
Asymp. Sig. (2-tailed)	.343	.000	.007	.319	.407	.866	.656

a. Wilcoxon Signed Ranks Test b. Based on positive ranks c. Based on negative ranks

All post_ and pre_ differences are mean differences.

Table 20

Wilcoxon Signed Ranks Test by Motivation subscale

Ranks

		N	Mean Rank	Sum of Ranks
Postmean – Premean	Negative Ranks	38[a]	33.00	1254.00
	Positive Ranks	28[b]	34.18	957.00
	Ties	1[c]		
	Total	67		
Post_AvgSE - Pre_AvgSE	Negative Ranks	40[d]	31.21	1248.50
	Positive Ranks	16[e]	21.72	347.50
	Ties	11[f]		
	Total	67		
Post_AvgALS - Pre_AvgALS	Negative Ranks	19[g]	21.87	415.50
	Positive Ranks	34[h]	29.87	1015.50
	Ties	14[i]		
	Total	67		
Post_AvgSLV - Pre_AvgSLV	Negative Ranks	24[j]	27.38	657.00
	Positive Ranks	23[k]	20.48	471.00
	Ties	20[l]		
	Total	67		
Post_AvgPG - Pre_AvgPG	Negative Ranks	23[m]	24.00	552.00
	Positive Ranks	27[n]	26.78	723.00
	Ties	17[o]		
	Total	67		
Post_AvgAG - Pre_AvgAG	Negative Ranks	26[p]	29.31	762.00
	Positive Ranks	28[q]	25.82	723.00
	Ties	13[r]		
	Total	67		
Post_AvgLES - Pre_AvgLES	Negative Ranks	25[s]	26.28	657.00
	Positive Ranks	24[t]	23.67	568.00
	Ties	18[u]		
	Total	67		

Note: Positive Rank: post_score> pre_score; Negative Rank: post_score<pre_score; Tie:post_score=pre_score

Mann-Whitney U-test. The Mann-Whitney U-test is the non-parametric inferential statistic test equivalent of the parametric independent sample *t*-test for difference in means by gender and for the ANOVA on the variation of means of the low, middle, and high achievers; pre and post argumentation.

The design assumptions of the Mann-Whitney U-test: (a) motivation is an ordinal dependent variable (b) the independent variable is categorical with two groups – Gender and any two levels of achievement. (c) independence of observation for the categorical groups; and the data assumption that the distribution of scores for the two categorical data have the same shape were met (Figure 24 and Figure 25):

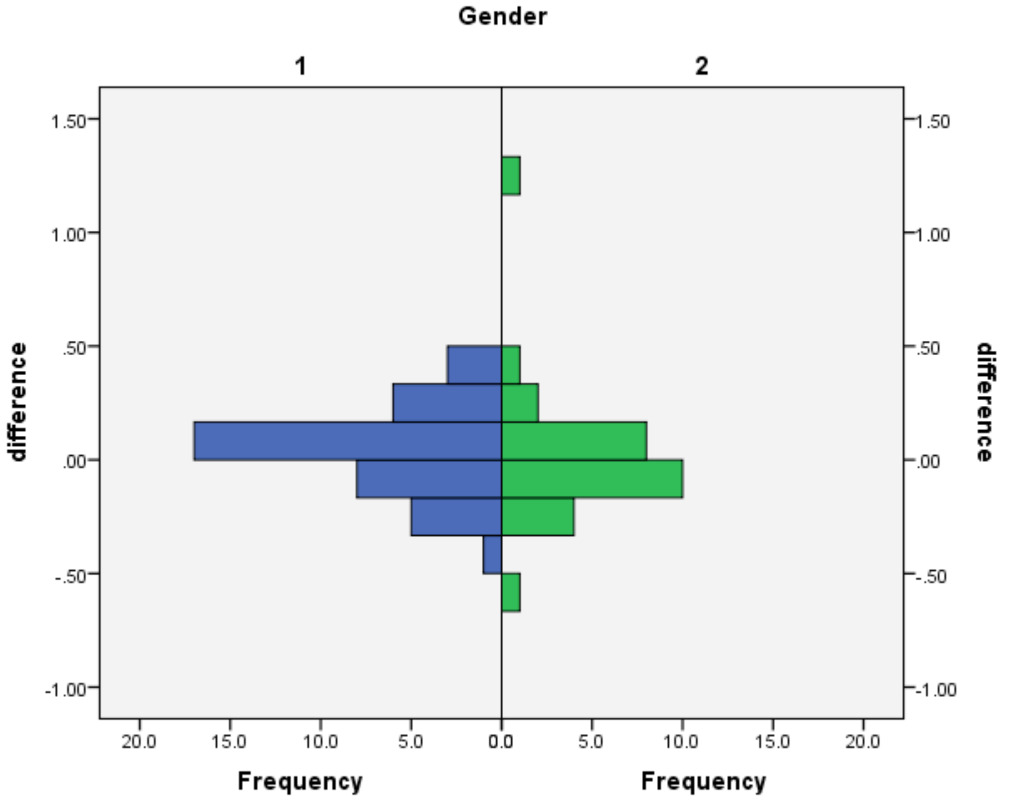


Figure 24. Distribution of difference between pre and post argumentation by Gender

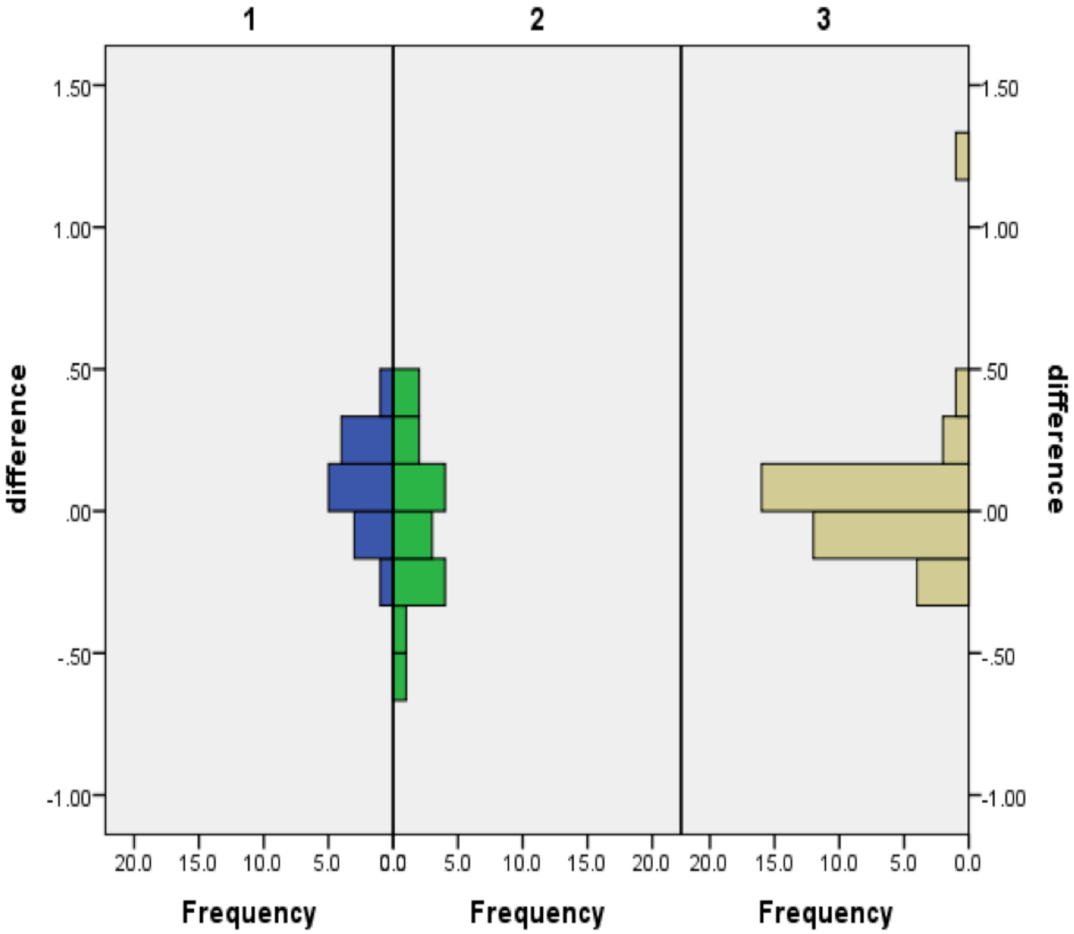


Figure 25. Distribution of difference between pre and post argumentation by Achievement (1 = Low achievers, 2 = medium achievers, 3 = high achievers)

The Mann-Whitney U test was run to determine if there were differences in motivation score between males and females before and after engaging in argumentation (Table 21). A Mann-Whitney U test was also run to determine if there were differences in change in motivation score between males and females between before and after engaging in argumentation (Table 22).

Table 21

Mann-Whitney Test by Gender

Gender	Premean	Postmean	Median difference
1	3.8191	3.7611	.0688
2	3.7567	3.7857	-.0016
Total	3.7950	3.7633	.0472

Note: 1 = Male; 2 = Female

Table 22

Test Statistics[a] *Mann-Whitney Test*

	Premean	Postmean	Difference
Mann-Whitney U	527.500	499.500	444.000
Wilcoxon W	905.500	1319.500	822.000
Z	-.160	-.518	-1.227
Asymp. Sig. (2-tailed)	.873	.605	.220

a. Grouping Variable: Gender

Before engaging in argumentation, the median motivation score for males (3.8191) and females (3.7567) was not statistically significantly different, U = 527.5, z = -.160, *p* = .873, using an exact sampling distribution for U (Dineen & Blakesley, 1973).

After engaging in argumentation, the median motivation score for males (3.7611) and females (3.7857) was not statistically significantly different, U = 499.5, z = -0.518, *p* = .605, using an exact sampling distribution for U (Dineen & Blakesley, 1973).

After engaging in argumentation, the median change in motivation score for males (0.0688) and females (-.0016) was not statistically significantly different, U = 444.00, z = -1.227, *p* = .220, using an exact sampling distribution for U (Dineen & Blakesley, 1973).

A Mann-Whitney U test was run to determine if there were differences in motivation score between low, middle, and high achievers before and after engaging in argumentation. A Mann-Whitney U test was also run to determine if there were differences in change in motivation score between low, middle, and high achievers between before and after engaging in argumentation Distributions of the motivation scores for different achievement levels were similar as shown below in Table 23.

Table 23

Mann-Whitney Test by Achievement Level

		Median	
Achievement	Premean	Postmean	difference
1	3.7323	3.5675	.1177
2	3.6732	3.7802	-.0905
3	3.9275	3.8379	.0449
Total	3.7950	3.7633	.0472

Note: 1 = Low Achievers, 2 = Middle Achievers, 3 = High Achievers.

Comparing low and high achievers. Before engaging in argumentation, the median motivation score for low achievers (3.7323) and high achievers (3.9275) was statistically significantly different, U = 138.00, z = -.2.463, *p* = .014, using an exact sampling distribution for U (Dineen & Blakesley, 1973).

After engaging in argumentation, the median motivation score for low achievers (3.5675) and high achievers (3.8379) was statistically significantly different, U = 102.5, z = -3.230, *p* = .001, using an exact sampling distribution for U (Dineen & Blakesley, 1973).

After engaging in argumentation, the median change in motivation score for low achievers (0.1177) and high achievers (0.0472) was not statistically significantly different, U = 184.00, z = -1.469, *p* = .142, using an exact sampling distribution for U (Dineen & Blakesley, 1973).

Table 24

Test Statistics[a] *Mann-Whitney Test by Achievement Levels1 & 3*

	Premean	Postmean	Difference
Mann-Whitney U	138.000	102.500	184.000
Wilcoxon W	243.000	207.500	850.000
Z	-2.463	-3.230	-1.469
Asymp. Sig. (2-tailed)	.014	.001	.142

a. Grouping Variable: Achievement

Comparing low and middle achievers. Before engaging in argumentation, the median motivation score for low achievers (3.7323) and middle achievers (3.6732) was not statistically significantly different, U = 108.00, z = 0.437, *p* = .681, using an exact sampling distribution for U (Dineen & Blakesley, 1973).

After engaging in argumentation, the median motivation score for low achievers (3.5675) and middle achievers (3.7802) was not statistically significantly different, U = 73.00, z = -1.826, *p* = .071, using an exact sampling distribution for U (Dineen & Blakesley, 1973).

After engaging in argumentation, the median change in motivation score for low achievers (0.1177) and middle achievers (-0.0905) was not statistically significantly different, U = 91.00, z = -1.111, *p* = .279, using an exact sampling distribution for U (Dineen & Blakesley, 1973).

Table 25

Test Statistics[a] *Mann-Whitney Test by Achievement Levels 1 & 2*

	Premean	Postmean	Difference
Mann-Whitney U	108.000	73.000	91.000
Wilcoxon W	213.000	178.000	244.000
Z	-.437	-1.826	-1.111
Asymp. Sig. (2-tailed)	.662	.068	.266
Exact Sig. [2*(1-tailed Sig.)]	.681[b]	.071[b]	.279[b]

a. Grouping Variable: Achievement
b. Not corrected for ties.

Comparing middle and high achievers. Before engaging in argumentation, the median motivation score for middle achievers (3.6732) and high achievers (3.9275) was not statistically significantly different, U = 217.00, z = -1.696, *p* = .090, using an exact sampling distribution for U (Dineen & Blakesley, 1973).

After engaging in argumentation, the median motivation score for middle achievers (3.7802) and high achievers (3.8379) and was not statistically significantly different, U = 250.00, z = -1.067, *p* = .286, using an exact sampling distribution for U (Dineen & Blakesley, 1973).

After engaging in argumentation, the median change in motivation score for low achievers (0.1177) and middle achievers (0.0449) was not statistically significantly different, U = 278.00, z = -0.534, *p* = .594, using an exact sampling distribution for U (Dineen & Blakesley, 1973).

Differences in motivation between low and high achievers is statistically significant both before and after engaging in argumentation but the change in their motivation as a consequence of argumentation is not statistically significant. Between middle and high achievers and between middle and low achievers the difference in motivation both pre and post argumentation and any changes in motivation as a consequence of argumentation are not statistically significant.

Table 26

Test Statisticsa Mann-Whitney Test by Achievement Level 2 & 3

	Premean	Postmean	Difference
Mann-Whitney U	217.000	250.000	278.000
Wilcoxon W	370.000	403.000	431.000
Z	-1.696	-1.067	-.534
Asymp. Sig. (2-tailed)	.090	.286	.594
a. Grouping Variable: Achievement			

Multiple Linear Regression model on the difference in scores with qualitative predictor of gender and achievement. The Ordinal Regression is used in place of a linear regression for an ordinal dependent variable given two or more independent variables. An additional assumption is that there is no multicolinearity or that the independent variables are not highly correlated. On running the colinearity test there was no colinearity between gender and achievement. However, given that the changes in motivation score were not statistically significant either by gender groups or achievement groups, I decided not to run the regression model as it would be redundant.

Table 27

Linear Regression Model Coefficients[a]

Model		Collinearity Statistics	
		Tolerance	VIF
1	Gender	.975	1.025
	Achievement	.975	1.025

a. Dependent Variable: difference

Evidence of Trustworthiness

The strategies described in chapter 3 to enhance the credibility of my study were carefully followed by (a) developing and using an interview protocol (b) recording one-on-one interviews with the teachers as I collected data on their plan to implement argumentation and transcribing the recordings (c) using the template developed to take notes of classroom discourse and (d) using the established methods – ESRU model to analyze teacher utterances, TAP features to analyze student responses, and coding to quantify argumentation (Erduran et al., 2004) – for data analysis. The breadth of classroom observation data gathered from four teachers in three disciplines of science provided evidence of the landscape of argumentation that grade nine students experienced. Using survey results for quantitative analysis data only from those students who completed both the pre and post argumentation survey also ensured accuracy of quantitative interpretation.

Following the week of classroom observation, I had a brief meeting with the four science teachers whose classes I observed. I shared with them a brief synopsis of my observation of their argumentation approach. As stated in their one-on-one interview, the teachers reiterated their approach to integrating argumentation as controlled by the teacher but allowing space for discussion among students when needed. However, teachers have not seen the in-depth analysis I have done of their classroom instruction and therefore member-check was limited by teachers' lack of knowledge of techniques to analyze argumentation.

The study is unique to the context in which it is undertaken—an integrated science class, each section being taught by two teachers: one with a masters degree in physical science and the other with a masters degree in biological science; and classroom instructions that typically don't leave much scope for open discussion but where teachers are experimenting with a more conversation based teaching-learning dynamic. Although the teachers have decided to adapt their teaching strategy to engage students in argumentation, they were not intentional about either incorporating Furtak's (2007)

ESRU model or paying attention to Toulmin's (1958) TAP features during argumentation. However, teachers' questions indicate their awareness of eliciting student application of science principles in their responses. The exercise of engaging students in argumentation was authentic and not directed by a research design for argumentation. Additionally, the data and analysis contain rich description of classroom discourse and inferential statistical analysis of students' response to the SMTSL instrument pre and post argumentation. The transferability of the study is therefore limited to situations where teachers have deep knowledge of the subject they teach and where teachers assume the role of professional practitioners who take the initiative to integrate argumentation in their class. However, the study will provide examples of how argumentation shapes in various disciplines within the sciences, which, I think, is transferable across all science teaching-learning contexts.

The dependability and confirmability of this study is enhanced because my notes accurately depict teacher interview responses and classroom discourse. Additionally, the analysis of data is carried out using established practices in understanding argumentation. Quantifying TAP features into dyads, triads, student questions, and rebuttals, helped to eliminate confusion about whether the statement uttered is a warrant or a backing (for example) and helped to look at the frequency with which higher order argumentation occurred. Furthermore, perceived gains from argumentation were considered from analyzing quantitative data provided by the school on student responses to the Student Motivation Towards Science Learning.

Summary

In this chapter I have presented findings from both qualitative and quantitative data. The data suggests that teachers used argumentation in their classes but there was no significant change in student motivation in science class as a consequence of engaging in a week of argumentation. In the next chapter I will discuss my results and lay out some probable reasons for my findings. I will discuss the scope and limitations of my study and suggest further research that can be done to address the limitations. I have also discussed in this chapter issues of trustworthiness of my study.

Chapter 5: Discussion, Conclusions, and Recommendations

The purposes of this mixed methods concurrent nested study were to understand how science teachers planned for and facilitated argumentation and to explore its consequent impact on student motivation in science class. Qualitative data were collected in two ways: through teacher interviews, which were designed to understand how teachers plan to facilitate argumentation in their classrooms, and through classroom observation. I conducted a secondary analysis of quantitative data, which were collected the school as part of its administration of the SMTSL instrument (Tuan, Chi-Chin, & Shyang-Horng, 2005) to students pre and post engagement in argumentation in their science classes. The school provided quantitative data to me as de-identified but matched pre and post argumentation.

The major findings of this study are

1. Teachers engaged students in argumentation by posing questions to the class. The questions and the prompts used by teachers followed Furtak's (2007) ESRU model. During the one-on-one interviews, none of the teachers explicitly stated that their conversational approaches were informed by Furtak's ESRU model. Therefore, my assumption is that teachers' ability to conduct discourse in their classes was reflective of their skills as educators. The first question from the teacher generally elicited response from students. Subsequent questions used and/or recognized student input and paved the way for further conversation on the principle of science or idea being discussed. Teachers created space that promoted student-to-student interactions as students built on responses from their

classmates. Student responses were supported with scientific reasoning and reflected the use of epistemic operators during reasoning. As students engaged in argumentation they seemed to be comfortable disagreeing with each other's responses in class and always provided an explanation to support their rebuttal.

2. Although teachers had collectively planned the week's lessons, they steered classroom conversation in their respective classes based on student responses. For example: discussions during the physics unit in class 9A were different from discussions in class 9B even though both classes worked on the same worksheet (see Table 4 and Table 10, Chapter 4). Each of the four teachers managed and directed classroom discourse—as they indicated during their one-on-one interviews—to provide space for students to verbalize their thoughts, but also to keep the conversations focused on the topic so that the time spent did not compromise the pace of syllabus coverage. As stated in point 1 above, the spontaneity with which teachers facilitated academic discourse in their class was reflective of their instructional practices. Follow-up questions and classroom discourse were not scripted, but reflected the evolution of thought process during learning.
3. Despite actively engaging in argumentation in the science class, there was no significant change in students' motivation (measured by students' self-reported perception on the Student Motivation Towards Science Learning instrument) in their science class. However, of the six constructs or sub-scales (self efficacy, active learning strategy, science learning value, goal orientation, performance

orientation, and learning environment stimulation) on the motivation scale, there was a significant decrease in students' *self-efficacy* to study science and a significant increase in students' *active learning* strategy in science as a consequence of engaging in argumentation.

Interpretation of Findings

In this section, I discuss the data presented in Chapter 4 with particular attention to the conceptual framework of argumentation and theoretical framework of motivation that I elaborated on in Chapter 2. Classroom observation data (qualitative data) and data from student survey responses (quantitative data) are discussed independently and then integrated to arrive at an answer to the research question: How does the use of argumentation in science instruction motivate students in science class? To the question during the on-on-one interview, about how argumentation would play out in their respective classes, all teachers indicated that the flow of conversation in class would be determined by student responses and questions.

Teachers also went on to say that they would use their discretion to decide the time devoted for teacher directed discourse. My classroom observations confirmed that teachers' facilitation of directed classroom discourse was spontaneous, authentic, and bound by learner needs, as indicated by teachers during the interviews. Hence, the first qualitative sub-question: *How do teachers plan to incorporate argumentation in their instruction?* Is integrated with the second qualitative sub-question: *How does argumentation occur in the classroom in terms of epistemic operators?* Under the *teacher practices in the classroom* section. Interpretation of survey data addresses the question:

To what extent does student motivation in the science class change after students engage in argumentation in class? and is discussed in the *survey findings* section. Findings from classroom observations of teachers' facilitation of argumentation and students' survey data are integrated at the end of the interpretation section to understand how the use of argumentation in science class impacted student motivation in the science class.

Teacher Practices in the Classroom

Classroom discourse fell under two broad categories, presentational and exploratory. Exploratory discourse (Mercer, 2004; Mercer & Hodgkinson, 2008) or directed dialogic discourse (Nurkka, Viiri, Littleton, & Lehesvuori, 2014) encouraged students to share and evaluate ideas, provide justifications, and to develop a collective understanding of science concepts. Teachers' questions exhibited elements of Furtak's (2010) ESRU model. Elements of Toulmin's (1958) argumentation pattern were evident in student responses. Students' claims, warrants (reasoning for the claim) and backings (justifications with science principles) were analyzed using epistemic operations. Both the nature of questions from the teachers and the responses from the students reflected that classroom discourse was substantive. The two examples of classroom discourse that follow provide evidence of the quality of argumentation in the science class. The first example is from a Biology class (see Table *7*). The teacher starts the classroom conversation with a knowledge retrieval question, but the conversation quickly moves towards exploration of the idea to bridge learning between chemistry and biology.

> *Teacher*: What is the difference between cuboidal epithelial tissue and glandular epithelial tissue? *[Here the teacher is eliciting response from students.]*

Student 1: Cuboidal tissue support the mechanical structure of an organ while the glandular tissue secrete hormones or enzymes.

Teacher: Correct. Where can we find these in the human body?

Student 2: Glandular tissue in the glands like pancreas to secrete insulin

Student 3: Cuboidal in kidney, and on the surface of various organs.

Student 4 (Question): Can an organ have both cuboidal and glandular tissues?

Teacher: Good question. Any responses? *[Here the teacher recognizes students' responses and uses them for further conversation in class. Additionally, the student question is directing classroom conversation, probably, not as anticipated by the teacher.]*

Student 3: Yes. Sweat glands can have cuboidal tissues to protect the gland from injury, but glandular tissue to help secrete sweat

Student 5: Why do we sweat more in summer or when we are nervous?

[This student question is not linked to the topic but is relevant and the teacher allows students to respond to the question.]

Student 6: In summer we drink a lot of water because we feel dehydrated so we sweat more.

[The teacher has sensed that the response is inappropriate and continues to answer student 5's question while correcting the response from student 6. The teacher makes connections to previous learning.]

Teacher: In chemistry you have studied evaporation. In summer the warm temperatures cause water to evaporate from the body surface – sweating. Therefore, we feel dehydrated and drink a lot of water.

[The conversation in class continues.]

It is evident that the classroom environment was conducive for argumentation. In addition to responding to teacher's question, students were comfortable asking questions and were engaged in co-construction of knowledge. It is also apparent that the teacher's plan for facilitating argumentation mirrors the *Learning Progressions* used by Berland & McNeil (2010) in their research. While the first two questions from the teacher elicited factual information, subsequent questions and responses from students directed the conversation towards drawing concepts of evaporation from a previous unit in chemistry. Additionally, when the teacher corrected the wrong response she helped to develop in students an understanding of why the correct response is correct (Osborne, 2010) and did not allow confusion to prevail for long.

The next example from a physics class provides evidence of emergence of new understanding as a student, through participation in argumentation, developed an agentic effort to take ownership of his learning (Ducshl, 2008) and revised his initial claim/response (see Table 11, Chapter 4).

Student 1 (original claim): There are three forces: gravity, air resistance, and friction with the ground.

Student 2(from another group): There is also the normal force from the ground when the ball touches it.

Student 3(from another group): At the highest point the force of gravity is the only force.

Student 1: Why not air resistance?

Student 3: Air resistance depends on speed. At the highest point the ball stops and therefore there is no air resistance.

Student 1(realizes his original answer is not fully accurate): Yes!

Student 4: But ball is not moving on the ground so friction is not important.

Student 2: Can normal force be friction?

Student 1(modifies his original response): I change my initial answer. There is no friction with the ground. There is normal force that pushes the ball back up but because the ball does not slide on the ground there is no friction.

Before student 1 changed his original answer he posed clarifying questions to his classmates. Additionally, student 1 was willing to revise his responses when other students in the class did not outright reject his answer, but provided explanations to support their view. In other words, during argumentation it is easier for students to arrive at a consensus when their disagreements are not confrontational but concessional (Berland & Lee, 2012) – a give and take exercise.

In both examples cited above, it is also evident that the teacher recognized and used student responses (Ruiz-Primo & Furtak, 2007) and students provided warrants to support their answers. While teachers generally phrased their questions to start with, "what, why do you think, can you explain, and how?" student answers drew on epistemic operators to support their warrants and backing to a claim, indicating that students were "doing science" (Jiménez-Aleixandre, Rodríguez, & Duschl, 1999). The argumentation in each of the classes, although limited to a quarter of the entire instructional time, engaged students in epistemic dialogue (Sandoval, 204; Manz, 2004), with the teacher playing a central role in scaffolding learning (Berland & McNeil, 2010; Ford & Wargo, 2011; Freeman, et al., 2014; Larrain, Howe, & Cerda, 2014). The teacher did not allow confusion to prevail for long and intervened in time to ensure that students' interest in the material was sustained (D'Mello, Lehman, Pekrun, & Grasser, 2014). Argumentation was framed as a schema of idea exchange between the teacher and students and between students. The conversations were fluid, students were making claims, supporting claims with evidence and reasoning, attending to and challenging each other's claims and evidence, although they had had essentially no formal presentation in skills of argumentation. Students also activated their previous knowledge to construct new meanings (Berland & Hammer, 2012).

Overall, from the one-on-one interview and the classroom observation data, I conclude that students experienced argumentation or teacher directed dialogic discourse in a range of contexts in their science classes. During small group discussions, all students were engaged in conversation (as evidenced from visual observation). During whole class discussions, students who were called upon to answer, and those who responded to their peers' answers, used scientific reasoning to justify their responses. Epistemic operators of deductive reasoning, classification, consistency with other knowledge, and appealing to analogy were frequently used in scientific reasoning. Although teachers did not explicitly lay out a script of how conversations would progress in class, they listened to their students' responses and built further communication around their students' questions and responses. In sum, the qualitative data showed extensive evidence of active learning through argumentation in the science class.

Survey Findings

Despite participating in argumentation in their science class there was no significant change in student motivation as indicated in their self-reported responses on the SMTSL instrument pre and post argumentation. Of the six constructs or sub-scales of motivation on the instrument: self-efficacy (SE), active learning strategies (ALS), science learning values (SLV), performance goal (PG), achievement goal (AG), and learning environment stimulation (LES); on deeper analysis, it was found that there was a statistically significant decrease in student self-efficacy (SE) and a statistically significant increase in students' active learning strategies (ALS) as a consequence of participation in argumentation.

Motivation is defined in social cognitive theory as "an internal state that arouses, directs, and sustains goal directed behavior" (Bryan, Glynn, & Kittleson, 2011, p. 1050). Of the six sub-scales of motivation in the SMTSL instrument, self-efficacy represents the learner's perception of his or her own ability to control the outcome of a task (Bandura, 1993) through their observations, thoughts, emotions, and collaborative work (Schunk, 1995). It is possible that since teachers' use of argumentation deviated from their conventional instructional practice, and also since the teachers did not explain (to the students) their plan to change instructional strategy, the students were confused by the increased level of dialogue in the class, despite participating in discussions. Osborne (2012), underscores the value of clearly defined goals and outcomes of classroom discourse for enhancing reasoning skills and conceptual understanding. Engagement in argumentation could have raised, in students' minds, questions about their understanding of the material, which consequently lowered their self-efficacy. However, this self-doubt may be temporary and could be followed by increased effort to learn the material. Additionally, although the teacher utterances recognized and used (Ruiz-Primo & Furtak, 2007) student responses in class, participation in argumentation did not provide students a measure of their immediate learning–a proximal goal (Bandura, 1985; Brooks & Young, 2011; Pintrich, 2003) of participation in the course–and therefore, in the short-term, students' confidence and self-efficacy may have declined as reflected in their survey responses. The tension between grade sensitivity and desire for deep learning (Higgins, Hartley, & Skelton, 2002) may have interfered with demonstrating significant gain in motivations as a consequence of engagement in argumentation – the value of which the students did not see. Furthermore, the gains from argumentation may be delayed (Asterhan & Schwarz, 2007; Osborne, 2010) and therefore students' self-efficacy—belief in their ability to perform well in science—immediately following argumentation may not be a good indicator of changes in motivation.

Active learning strategies (ALS), a category of motivation on the SMTSL instrument, is a measure of student affect as they use a variety of strategies to construct new knowledge (Tuan, et. al. 2005). Argumentation in the chemistry lab, during discussion of review worksheet for physics, and interspersed with instruction in biology, provided students with a range of contexts in which to practice their reasoning skills. Learners actively engaged both within small groups (physics worksheet and lab groups) and whole-class responses, to apply their knowledge and to demonstrate their understanding. Although some students could be vicariously engaged during classroom discourse, they had the opportunity to compare their thoughts with responses provided by their classmates, and thus maximized their learning through self-reflection and self-evaluation (Deci et. al, 1991; Panadero, Alonso-Tapia, & Reche, 2013). A significant increase in students' active learning strategies as a consequence of engaging in argumentation—for some students through experiencing affirmation from their teacher and from their peers, and for other students, through the exercise of comparing their answers with those of their peers as teachers recognized and used student responses—therefore alludes to the benefits of engaging students in argumentation.

As stated in the background section of chapter 1 there is research on how to improve student motivation through feedback (Black & William, 2004; Ruiz-Primo & Furtak, 2007; Coffey, Heritage, 2010; Minstrell, Anderson, & Li, 2011; Hammer, Levin, & Grant, 2011) and active learning strategies (Duit & Treagust, 2003; Freeman et.al 2013) but there is no study that links student motivation in science class to their engagement in argumentation in the class. Since argumentation during instruction involves formative feedback and actively engages students' thinking, I expected motivation of students in science class to rise as a consequence of engaging in argumentation. Hence, I was surprised to see self-efficacy significantly decrease and no significant change in two motivation categories—learning environment stimulation and science learning value. According to Tuan et al. (p. 648, 2005) learning environment stimulation (LES) and science learning value (SLV) are positively correlated with students’ attitude towards science. Since both LES and SLV did not change significantly it is apparent that the week of engaging in argumentation did not impact students’ attitude towards science. I also believe that since a majority of the student participants was high achievers (34 out of 67), engagement in the week of argumentation did not significantly alter their performance goal (PG) and achievement goal (AG) for science. I would therefore conclude that the novelty of engaging in argumentation in the science class was stimulating for the students which was reflected in the significant increase in the motivation sub-scale active learning strategy, but the one-week duration of engaging in argumentation was too short to significantly impact student motivation in science class.

Prior research has either analyzed teacher utterances using the ESRU model or analyzed student responses during argumentation using epistemic operators and TAP features, but no study has brought together the analysis of teacher utterances and student responses within the same framework, like the analysis I have undertaken. Additionally, most research on argumentation in science classes was designed by researchers and implemented by teachers under the guidance (and training) of researchers undertaking their study, unlike my dissertation where argumentation in class was planned and facilitated by the teachers. Hence my research is novel and adds to the knowledge base of analysis of argumentation, particularly in authentic teaching-learning contexts. Furthermore, no research has quantitatively assessed students on changes in their motivation as a consequence of engaging argumentation in their science classes. This mixed methods approach is therefore unusual in tying students’ perception about changes in their motivation to engagement in argumentation in their science class.

This mixed methods study that collects data from more than one category of stakeholders emulates program evaluation and therefore raises a question about science pedagogy—whether argumentation is sufficient to increase motivation of students in the science class. The significant increase in the motivation sub-scale, students' active learning strategy in science, affirms that argumentation is an active learning strategy. However, a significant decrease in the motivation sub-scale, students' self-efficacy, indicates that argumentation may not be the best approach to improve students' confidence to complete tasks in the science class. Additionally, no change in the motivation sub-scales, performance goal, science learning value, achievement goal, and learning environment stimulation indicates that there may be other pedagogical approaches suited for enhancing motivation in each of these categories. Based on my findings, I conclude that motivation is a complex construct with many factors that impact it and therefore teachers must use a suite of pedagogical approaches in order to enhance motivation in science class.

Limitations of the Study

This mixed methods concurrent nested study is based on data collected at one school. Thirty-four (about 50%) out of sixty-seven students who completed the SMTSL survey were high achievers, who probably are highly motivated at the beginning of the study, and therefore did not indicate a change in motivation as a consequence of engaging in argumentation. Collecting both qualitative and quantitative data concurrently did not allow for focusing either on students with different levels of motivation or engagement during argumentation, or on the value of certain context of argumentation (lab work, review worksheet, or embedded in instruction) on student motivation. Hence, although the level of argumentation was substantively strong—teacher utterances intuitively matched with the ESRU (Ruiz-Primo & Furtak, 2007) model and student responses naturally contained justifications (warrants and backing)—it was not possible to triangulate or to correlate approaches to argumentation and their impact on student motivation.

While student survey responses provided quantitative data (from the perspective of students) on changes in motivation due to engagement in argumentation in science class, interviews with students would provide additional information about the approaches teachers used during dialogic discourse that had impact on student motivation. Additionally, most nested designs tend to follow a confirmatory model (Small, 2011) and it is therefore helpful to collect concurrent data over extended period of time to establish trends in changes as opposed to arriving at a conclusion based on a snap-shot in time. One week of observation to evaluate changes in motivation measured by students' self-reported perception on the SMTSL instrument is a short period. In addition, changes in learning (and therefore in motivation) can be delayed after an intervention. Future studies should undertake quantitative data collection for analysis for a longer period of engagement in argumentation. Furthermore, as data was not collected during small group discussions, and certain students were answering more frequently, particularly during the period when students spontaneously responded to each other, it is difficult to connect these students' individual changes in motivation to whole-class changes in motivation as a consequence of engagement in argumentation.

This mixed methods concurrent nested approach in which I both interviewed and observed teachers in their planning process and classroom practice, and surveyed students regarding their level of motivation, allowed me to view the concept of motivation and practice of argumentation from two complementary perspectives (Creswell, 2007; Cronhlom & Hjalmarsson, 2011; Small, 2011) – teachers and students. Teachers successfully facilitated argumentation to increase student engagement. However, students' increased engagement only showed a significant improvement in *active learning strategy* (a motivation subscale on the SMTSL instrument). Hence, the findings of the study allow for neither confirmatory nor integrative conclusions. Expanding the time over which students respond to motivation survey pre– and post–argumentation, and probably collecting and analyzing changes in motivation within different contexts of argumentation—lab based, embedded during lecture, or small group presentation—will provide greater validity to connections between motivation and argumentation.

Other limitations of this study include the varying attendance to class through the week. Out of 90 students only 67 were present on the day that the pre– and post–argumentation survey was given. It is possible that some of these students were absent for a day or two of instruction during the week just as a few students who were present either on the pre–argumentation survey day or on the post–argumentation survey day. Additionally, changes in student motivation could be an outcome of factors outside the science class, for example another subject. Furthermore, the teachers did not inform the class of their plan to use argumentation in class. It is possible that the students were confused with the changed instructional strategy and did not enjoy the process of being engaged in argumentation or found the entire process of argumentation distracting compared to their conventional teaching–learning experience.

Recommendations

The learning from this study can be used as a basis for additional research on connections between argumentation and motivation. Although there is extensive research on the value of argumentation in elevating student achievement both in the short term and in the long term, and although student motivation and students' achievement are positively correlated, further studies on impact of argumentation on student motivation will be helpful. In particular, the survey results show that although there was no significant change in student motivation (collectively on the six categories of motivation on the SMTSL instrument) as a consequence of engagement in argumentation, there was a significant decrease in the motivation category *self-efficacy* and a significant increase in the motivation category *active learning strategies*. I recommend further study to (a) confirm or disconfirm my explanations about why self-efficacy decreased and (b) to understand how argumentation can be facilitated to improve student motivation in all categories of motivation – self efficacy, active learning strategy, learning environment stimulation, performance goal, achievement goal, and science learning value.

Although this study focused on assessing the motivation of the entire cohort of ninth grade students, I recommend future research to explore whether students who engage in more discussion—either explaining their position or disagreeing with a classmates' explanation— experience greater changes in motivation compared to their classmates who engage in less discussion. The study that focuses on analyzing changes in motivation as frequency of engagement in argumentation changes will help to shed light on the vicarious learning theory of motivation. Such a study would collect observation and survey data concurrently, but students will have to be identified and categorized by their frequency of engagement in argumentation for quantitative analysis.

Students in this study were enrolled in an integrated science course. They experienced argumentation in different contexts—a discussion of lab procedure in chemistry, an application of principles of Newtonian Mechanics, and exploratory talk of epithelial tissues in biology—and it was not possible to discern how each of these contexts contributed to changes in student motivation in the science class. I recommend future research that evaluates the impact on student motivation of the context in which argumentation occurs.

My fourth recommendation stems from the idea of learning progressions (Berland & McNeil, 2010; Osborne, 2010) where the teacher, based on his/her learning from classroom discourse, redefines instructional goals for enhanced conceptual understanding. Designing a study where teachers are comfortable adapting their lesson plans to address gaps in students' understanding of material, can bring out the connection between argumentation and formative feedback, and probably shed some light on how argumentation can improve motivation.

In the absence of notes on the interactions within individual groups as students arrived at a consensus for the group response (Berland & Lee, 2012), it was difficult to understand whether the answer was arrived at by one member of the group or by actual negotiations between members of the group. Research that integrates both small group and whole-class argumentation to understand how the process of arriving at a group response has an impact on student motivation is the fifth recommendation.

Students' grade sensitivity may interfere with their purposeful engagement in argumentation and with their perception of the value of argumentation (Brown, Harris, & Harnett, 2012; Higgins, Hartley, & Skelton, 2012; Panadero, Alonso-Tapia, & Reche, 2013). Finally, I recommend future study similar to Minstrell, Anderson, & Li (2011), which integrates epistemic argumentation in assessment models to explore the effect assessment has on student motivation to engage in substantive argumentation.

Implications of the Study

Social Change Implications

Teachers' initiative to try a new pedagogical approach developed their competency to engage students in argumentation and consequently promoted their individual and collective professional efficacy. Working together in the planning and probably in evaluating the facilitation of argumentation in their classes, they developed insight into how students think as they apply science concepts. The study provides an example of professional development through teacher practitioner model, a professional skill that helps teachers to be reflective of their own practice and responsive to the needs of students in particular, and to education in general. This study provides an example of teacher leadership in educational practice.

Theoretical Implications

The examples of argumentation in different science classes either as a consequence of teacher directed questions or as a result of student initiated questions and examples of negotiations among students around disagreements provides evidence of class dynamics that have a direct bearing on student learning. Educational practitioners can critique their lessons by drawing similarities or focusing on how their classroom dynamics differs from the examples in this study. The context of this study provides one more example of argumentation, which adds to the literature and probably helps in developing a comprehensive understanding of the phenomenon, particularly with respect to education responding to the learner needs. Argumentation is an active learning strategy and argumentation in each discipline has its epistemic operators for effective learning, and this study brings together an analysis of teacher utterances and student responses to look at the landscape of argumentation.

Conclusion

Argumentation is dynamic and within the academic domain its purpose is to enhance student learning. In the ninth grade integrated science course students were engaged in argumentation in a range of contexts: during instruction of new material in biology, lab work in chemistry, and review and application of concepts during small group work in physics. Classroom observation data validated data collected from teachers' one-on-one interview on how they planned to facilitate argumentation. The teacher utterances that were observed contained elements of the ESRU model, students followed Toulmin's argumentation pattern and the warrants and backings contained epistemic operators. Mostly, class discussions were directed by teacher questions, but there were instances where student initiated questions led to deeper understanding of ideas particularly when one student changed his original answer based on the discussion in class. Rebuttals from students never openly challenged other students' answers, but were presented in the form of, "I think…," and generally were followed by a warrant to support the claim. Argumentation is also a complex process that engages the social, cognitive, and affective domains of learning.

Statistical analysis of quantitative data (secondary) collected as student self-reported perception on the SMTSL instrument, showed that there was no significant change in student motivation in science class as a result of engagement in argumentation despite the supportive learning environment in which dialogic discourse occurred. Deeper analysis of the individual criteria for motivation showed that there was a significant decrease in self-efficacy and a significant increase in active learning strategy as a consequence of engagement in argumentation for the entire cohort of ninth grade students. Within the limitations of the study, it is safe to conclude that since argumentation is an active learning approach, it can have a significant impact on active learning strategy on the motivation scale, but also since the exercise of engaging in argumentation was new for the students their confidence to study the subject did not change significantly. The study therefore points out that argumentation may not uniformly impact all constructs or sub-scales (as identified by the SMTSL instrument) of motivation.

The use of the mixed-methods concurrent nested study came about as a result of an interest in understanding students' perception of impact of pedagogical practices on their motivation in science. Educational research mostly looks at students' grades to analyze the effect of in intervention. However, rarely are students asked to describe or identify how they experienced the intervention. I therefore decided to add student voice in the analysis of a pedagogical approach teachers thought would have an impact on student engagement in class. Although student performance on assessments is considered to be correlated with students' motivation in a course, I decided to focus on motivation alone because there can be instances where test taking skills, prior knowledge, or grade sensitivity (extrinsic motivation) can lead to higher performance on assessments. It was also important to evaluate classroom dialogic discourse—were teacher instructional utterances directed towards learning goals? Did student responses include discipline specific vocabulary? And was the classroom environment conducive to exchange of ideas? —against the established parameters of epistemic conversations.

My study incorporates input from two important stakeholders in the teaching-learning dynamics: students and teachers. In addition to underscoring the value of engaging stakeholders who are impacted by an intervention in data collection, the research opens the door for further study on engaging in argumentation and its impact on learner motivation. A new interest that has emerged for me is to understand what kind of teaching–learning dynamic impacts each category of motivation in science learning.

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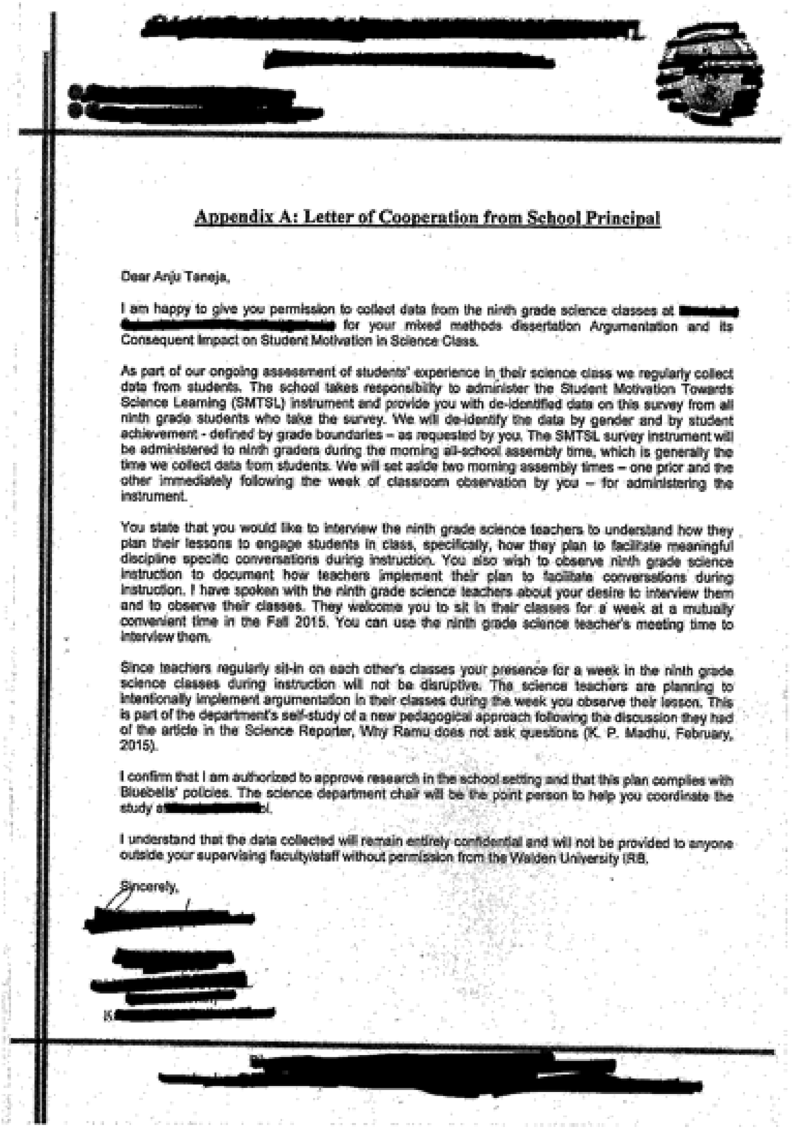
Appendix A: Letter of Cooperation from School Principal



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Appendix A: Letter of Cooperation from School Principal

Dear Anju Taneja,

I am happy to give you permission to collect data from the ninth grade science classes at [redacted] for your mixed methods dissertation Argumentation and its Consequent Impact on Student Motivation in Science Class.

As part of our ongoing assessment of students' experience in their science class we regularly collect data from students. The school takes responsibility to administer the Student Motivation Towards Science Learning (SMTSL) instrument and provide you with de-identified data on this survey from all ninth grade students who take the survey. We will de-identify the data by gender and by student achievement - defined by grade boundaries – as requested by you. The SMTSL survey instrument will be administered to ninth graders during the morning all-school assembly time, which is generally the time we collect data from students. We will set aside two morning assembly times – one prior and the other immediately following the week of classroom observation by you – for administering the instrument.

You state that you would like to interview the ninth grade science teachers to understand how they plan their lessons to engage students in class, specifically, how they plan to facilitate meaningful discipline specific conversations during instruction. You also wish to observe ninth grade science instruction to document how teachers implement their plan to facilitate conversations during instruction. I have spoken with the ninth grade science teachers about your desire to interview them and to observe their classes. They welcome you to sit in their classes for a week at a mutually convenient time in the Fall 2015. You can use the ninth grade science teacher's meeting time to interview them.

Since teachers regularly sit-in on each other's classes your presence for a week in the ninth grade science classes during instruction will not be disruptive. The science teachers are planning to intentionally implement argumentation in their classes during the week you observe their lesson. This is part of the department's self-study of a new pedagogical approach following the discussion they had of the article in the Science Reporter, Why Ramu does not ask questions (K. P. Madhu, February, 2015).

I confirm that I am authorized to approve research in the school setting and that this plan complies with Bluebells' policies. The science department chair will be the point person to help you coordinate the study [redacted].

I understand that the data collected will remain entirely confidential and will not be provided to anyone outside your supervising faculty/staff without permission from the Walden University IRB.

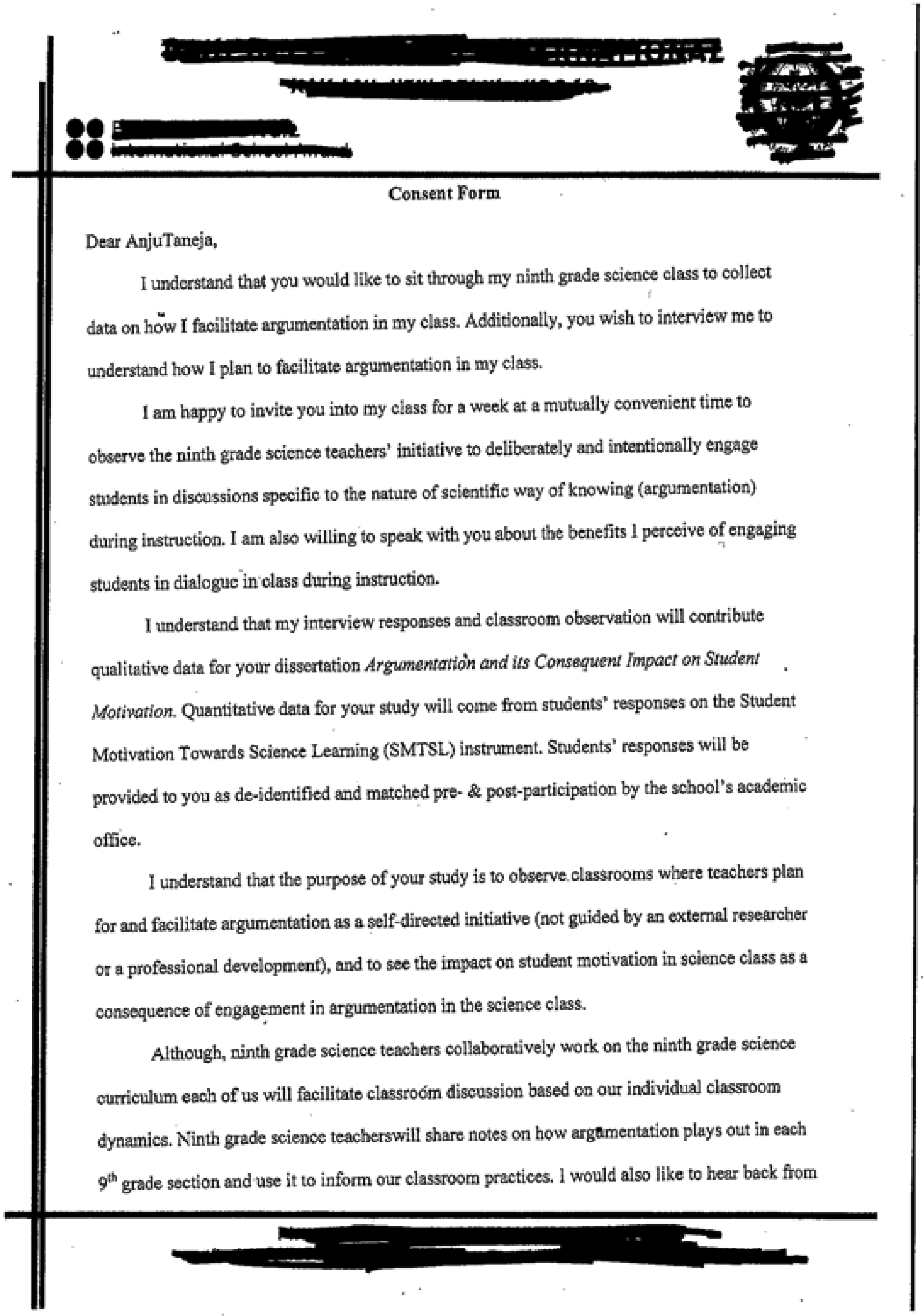
Sincerely,

[redacted]

[redacted]

[redacted]

Appendix B: Teacher Consent Form



[redacted]

[redacted]

[redacted]

Consent Form

Dear AnjuTaneja,

I understand that you would like to sit through my ninth grade science class to collect data on how I facilitate argumentation in my class. Additionally, you wish to interview me to understand how I plan to facilitate argumentation in my class.

I am happy to invite you into my class for a week at a mutually convenient time to observe the ninth grade science teachers' initiative to deliberately and intentionally engage students in discussions specific to the nature of scientific way of knowing (argumentation) during instruction. I am also willing to speak with you about the benefits I perceive of engaging students in dialogue in class during instruction.

I understand that my interview responses and classroom observation will contribute qualitative data for your dissertation *Argumentation and its Consequent Impact on Student Motivation*. Quantitative data for your study will come from students' responses on the Student Motivation Towards Science Learning (SMTSL) instrument. Students' responses will be provided to you as de-identified and matched pre- & post-participation by the school's academic office.

I understand that the purpose of your study is to observe classrooms where teachers plan for and facilitate argumentation as a self-directed initiative (not guided by an external researcher or a professional development), and to see the impact on student motivation in science class as a consequence of engagement in argumentation in the science class.

Although, ninth grade science teachers collaboratively work on the ninth grade science curriculum each of us will facilitate classroom discussion based on our individual classroom dynamics. Ninth grade science teacherswill share notes on how argumentation plays out in each 9th grade section and use it to inform our classroom practices. I would also like to hear back from

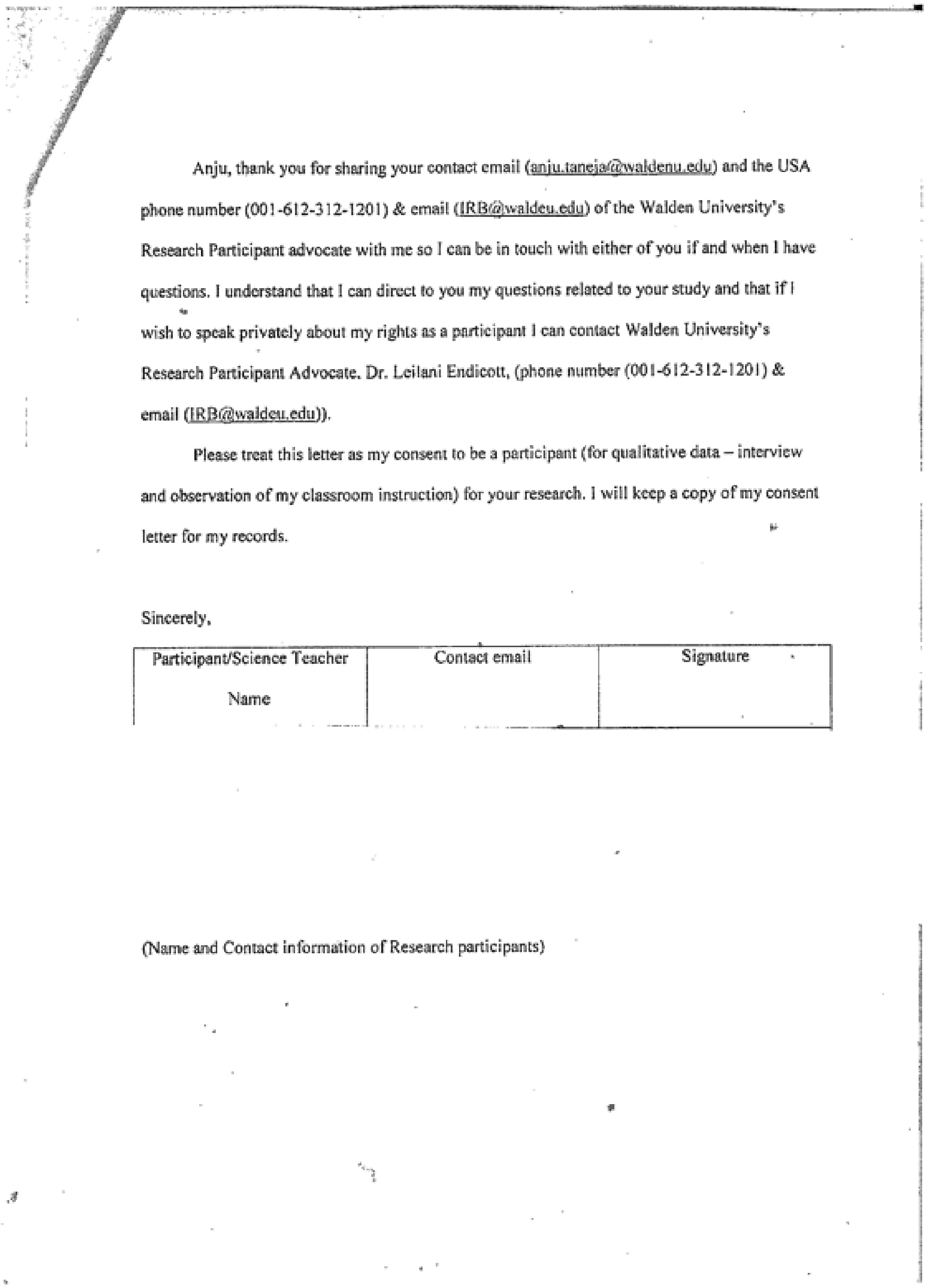
[redacted]

you of your findings based on analysis of qualitative and quantitative data. Additionally, although your findings may not inform the way I teach, I do see its value for the community of science teachers and for further research on the practice of argumentation in science classes.

My invitation to you to observe my class while I facilitate argumentation is voluntary and intended to support your dissertation. I am aware that you will follow my teaching schedule to sit in my science classes and that I am not modifying the content I teach, my instruction, or my teaching schedule to accommodate your data collection. I teach about 5 hours of science per week to my 9th graders. I expect to see you in my classroom for the week of observation at a mutually convenient time. I am also happy to meet with you one-on-one for about 30 minutes before the week of classroom observation to speak about my plan to facilitate argumentation.

I am aware that the SMTSL instrument will not be administered during the academic class time and that I am not responsible for administering the instrument for my 9th grade section. The academic office will collect student responses on the instrument during the morning assembly time and provide you with de-identified data matched pre- and post-participation in argumentation. Each student will be able to respond to the SMTSL instrument in approximately 15 minutes.

I am aware that I can withdraw at any time during your visit (data collection) my invitation to you to sit through my class or to participate in the interview. I am not receiving any compensation from you or from any other agency to allow you to collect data for your dissertation. I understand that the data you gather from my class will remain confidential and that you will use pseudo name to protect my identity in your written dissertation. I do not see any foreseeable risks of the data on my performance evaluation as an instructor or on my instructional practice or on my students' confidence in my instruction.



Anju, thank you for sharing your contact email (anju.taneja@waldenu.edu) and the USA phone number (001-612-312-1201) & email (IRB@waldeu.edu) of the Walden University's Research Participant advocate with me so I can be in touch with either of you if and when I have questions. I understand that I can direct to you my questions related to your study and that if I wish to speak privately about my rights as a participant I can contact Walden University's Research Participant Advocate. Dr. Leilani Endicott, (phone number (001-612-312-1201) & email (IRB@waldeu.edu)).

Please treat this letter as my consent to be a participant (for qualitative data – interview and observation of my classroom instruction) for your research. I will keep a copy of my consent letter for my records.

Sincerely,

Participant/Science Teacher Name	Contact email	Signature

(Name and Contact information of Research participants)

Appendix C: Strategies for ESRU Cycle by Dimension

Eliciting	Recognizing	Using
Epistemic Frameworks Teacher asks students to: • Compare/contrast observations, data, or procedures • Use and apply known procedures • Make predictions, provide hypotheses • Interpret information, data, patterns • Provide evidence and examples • Relate evidence and explanations • Formulate scientific explanations • Evaluate quality of evidence • Suggest hypothetical procedures or experimental plans • Compare/contrast others' ideas • Check students' comprehension Conceptual structures Teacher asks students to: • Provide potential or actual definitions • Apply, relate, compare, contrast concepts • Compare/contrasts others' definitions or ideas • Check their comprehension	Teacher: • Clarifies/Elaborates based on students' responses • Takes votes to acknowledge different students' ideas • Repeats/paraphrases students words • Re-voices students' words (incorporates students' contributions into the class conversation • summarizes what student said, acknowledge student contribution) • Captures/displays students' responses/explanations	Teacher: • Promotes students' thinking by asking them to elaborate their responses (why, how) • Compares/contrasts students' responses to acknowledge and discuss alternative explanations • Promotes debating and discussion among students' ideas /conceptions • Helps students to achieve consensus • Helps relate evidence to explanations • Provides descriptive or helpful feedback • Promotes making sense • Promotes exploration of students' own ideas • Refers explicitly to the nature of science • Makes connections to previous learning

Appendix D: Interview Questions for Teachers

1. Can you describe the unit you will be teaching this week in your science class? What are some of the difficult ideas in this topic for students? Why do you think these ideas are difficult for the students?
2. Can you explain why the team of ninth grade science teachers decided to experiment with using argumentation in their classes?
3. In your mind, how would argumentation play out in class?
4. How do you (and the team of ninth grade teachers) plan to incorporate argumentation in class? How will your class for this week be different from/similar to your classes in the last week? Month?
5. Can you tell me if you anticipate any challenges in facilitating argumentation in your class?
6. Is there anything else you would like to share with me about your class before I sit in your class? Would you like me to sit at a particular place in the class?

Appendix E: Protocol for Classroom Observation

Table E.1

Rubric to categorize classroom discourse

Nature of discourse	Descriptors
Teacher Presentation (TP)	• Teacher speaks and delivers information
Teacher directed authoritative discussion (AD)	• Teacher responses are generally of the nature to seek right/wrong answers, • Teacher is quick to provide the correct answer to questions.
Teacher directed dialogic discussion (DD)	• Teacher questions and comments are based on ESRU model • Student responses use epistemic operators in explanations • Elements of TAP present in sequence of conversation.
Student Initiated (SI)	• student asks question in response to teacher presentation, or in response to teacher question or in response to another student's comment

Note. (adapted from Nurkka, Viiri, Littleton, & Lehesvuori, 2014)

Table E.2

Template (in Excel) to take notes of classroom discourse

Time (minutes)	TP	AD	DD	SI
	Comments on delivery of lesson recorded here	Special attention will be paid to wording of teacher comments (ESRU epistemic framework) and student responses (TAP features)		

Appendix F: Classroom Observation Templates

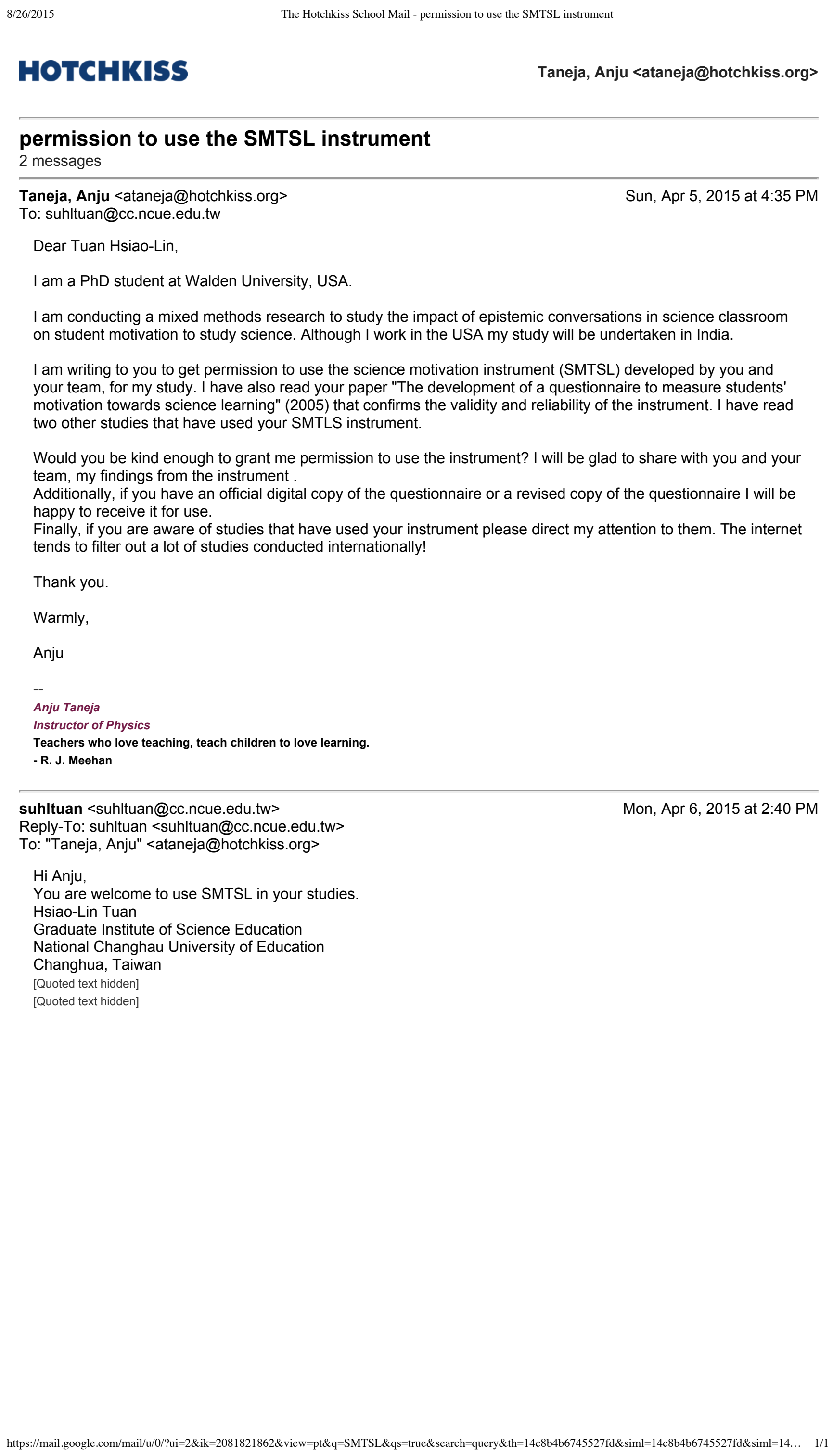
Table F

Template for Documenting Teacher-Directed Dialogic Discourse

Teacher comment/question		Student responses and chain of conversation		
Write each comment/question verbatim	ESRU factors	Write the comments verbatim	TAP feature/s (epistemic operator)	Duration of conversation

(Epistemic operators adapted from Jiménez-Aleixandre, Rodríguez, and Duschl (1999); TAP features adapted from Erduran, Simon and Osborne (2004); and ESRU model adapted from Ruiz-Primo and Furtak (2007)

Appendix G: Permission to Use the Student Motivation Towards Science Learning



8/26/2015 The Hotchkiss School Mail - permission to use the SMTSL instrument

HOTCHKISS

Taneja, Anju <ataneja@hotchkiss.org>

permission to use the SMTSL instrument

2 messages

Taneja, Anju <ataneja@hotchkiss.org> Sun, Apr 5, 2015 at 4:35 PM

To: suhltuan@cc.ncue.edu.tw

Dear Tuan Hsiao-Lin,

I am a PhD student at Walden University, USA.

I am conducting a mixed methods research to study the impact of epistemic conversations in science classroom on student motivation to study science. Although I work in the USA my study will be undertaken in India.

I am writing to you to get permission to use the science motivation instrument (SMTSL) developed by you and your team, for my study. I have also read your paper "The development of a questionnaire to measure students' motivation towards science learning" (2005) that confirms the validity and reliability of the instrument. I have read two other studies that have used your SMTLS instrument.

Would you be kind enough to grant me permission to use the instrument? I will be glad to share with you and your team, my findings from the instrument .
Additionally, if you have an official digital copy of the questionnaire or a revised copy of the questionnaire I will be happy to receive it for use.
Finally, if you are aware of studies that have used your instrument please direct my attention to them. The internet tends to filter out a lot of studies conducted internationally!

Thank you.

Warmly,

Anju

--
Anju Taneja
Instructor of Physics
Teachers who love teaching, teach children to love learning.
- R. J. Meehan

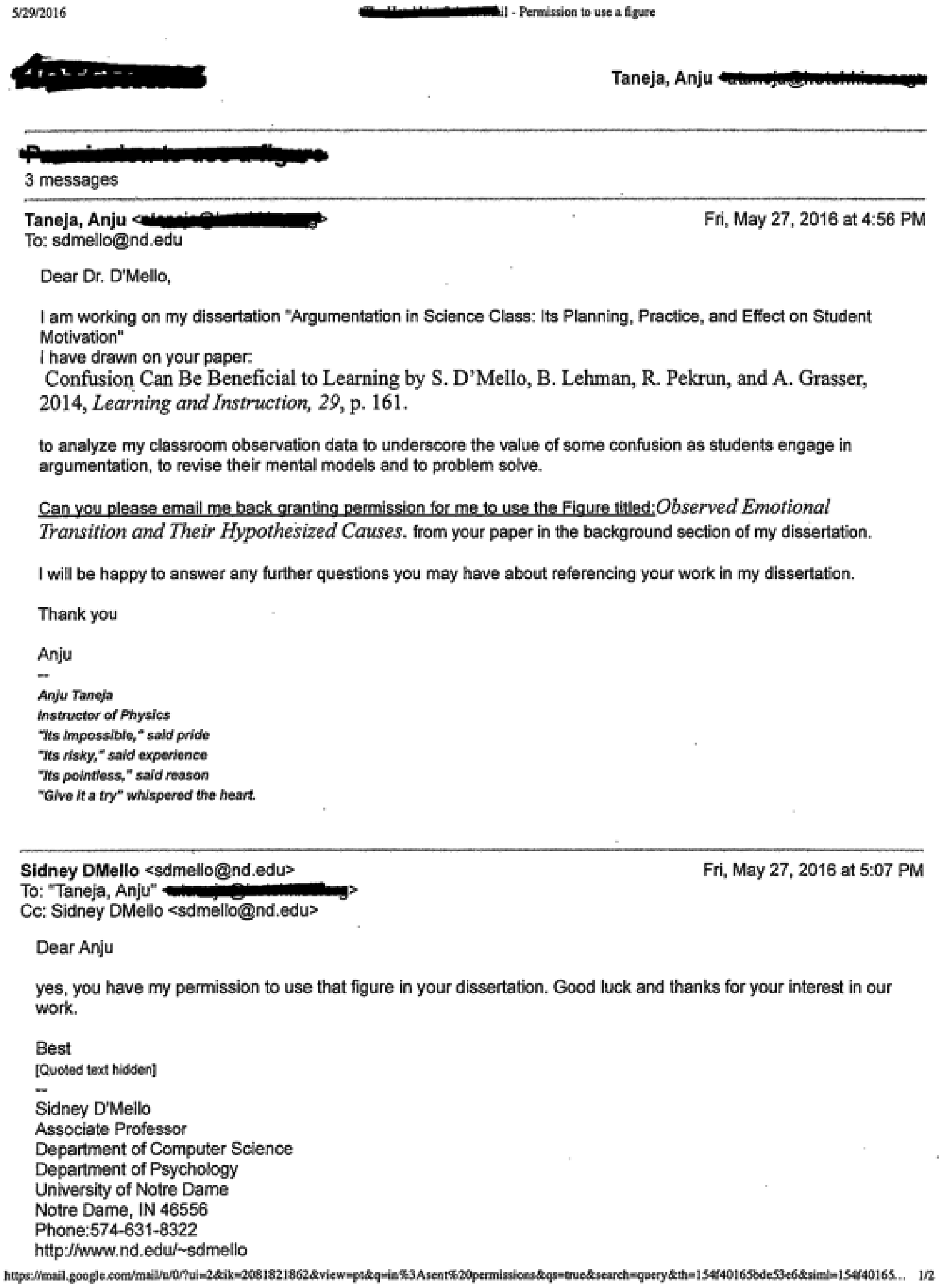
suhltuan <suhltuan@cc.ncue.edu.tw> Mon, Apr 6, 2015 at 2:40 PM

Reply-To: suhltuan <suhltuan@cc.ncue.edu.tw>
To: "Taneja, Anju" <ataneja@hotchkiss.org>

Hi Anju,
You are welcome to use SMTSL in your studies.
Hsiao-Lin Tuan
Graduate Institute of Science Education
National Changhau University of Education
Changhua, Taiwan
[Quoted text hidden]
[Quoted text hidden]

https://mail.google.com/mail/u/0/?ui=2&ik=2081821862&view=pt&q=SMTSL&qs=true&search=query&th=14c8b4b6745527fd&siml=14c8b4b6745527fd&siml=14… 1/1

Appendix H 1: Permission to use Figure



5/29/2016 [redacted]il - Permission to use a figure

[redacted]

Taneja, Anju [redacted]

[redacted]

3 messages

Taneja, Anju <[redacted]> Fri, May 27, 2016 at 4:56 PM
To: sdmello@nd.edu

Dear Dr. D'Mello,

I am working on my dissertation "Argumentation in Science Class: Its Planning, Practice, and Effect on Student Motivation"
I have drawn on your paper:
Confusion Can Be Beneficial to Learning by S. D'Mello, B. Lehman, R. Pekrun, and A. Grasser, 2014, *Learning and Instruction, 29*, p. 161.

to analyze my classroom observation data to underscore the value of some confusion as students engage in argumentation, to revise their mental models and to problem solve.

Can you please email me back granting permission for me to use the Figure titled:*Observed Emotional Transition and Their Hypothesized Causes*. from your paper in the background section of my dissertation.

I will be happy to answer any further questions you may have about referencing your work in my dissertation.

Thank you

Anju

--

Anju Taneja
Instructor of Physics
"Its impossible," said pride
"Its risky," said experience
"Its pointless," said reason
"Give it a try" whispered the heart.

Sidney DMello <sdmello@nd.edu> Fri, May 27, 2016 at 5:07 PM
To: "Taneja, Anju" [redacted]>
Cc: Sidney DMello <sdmello@nd.edu>

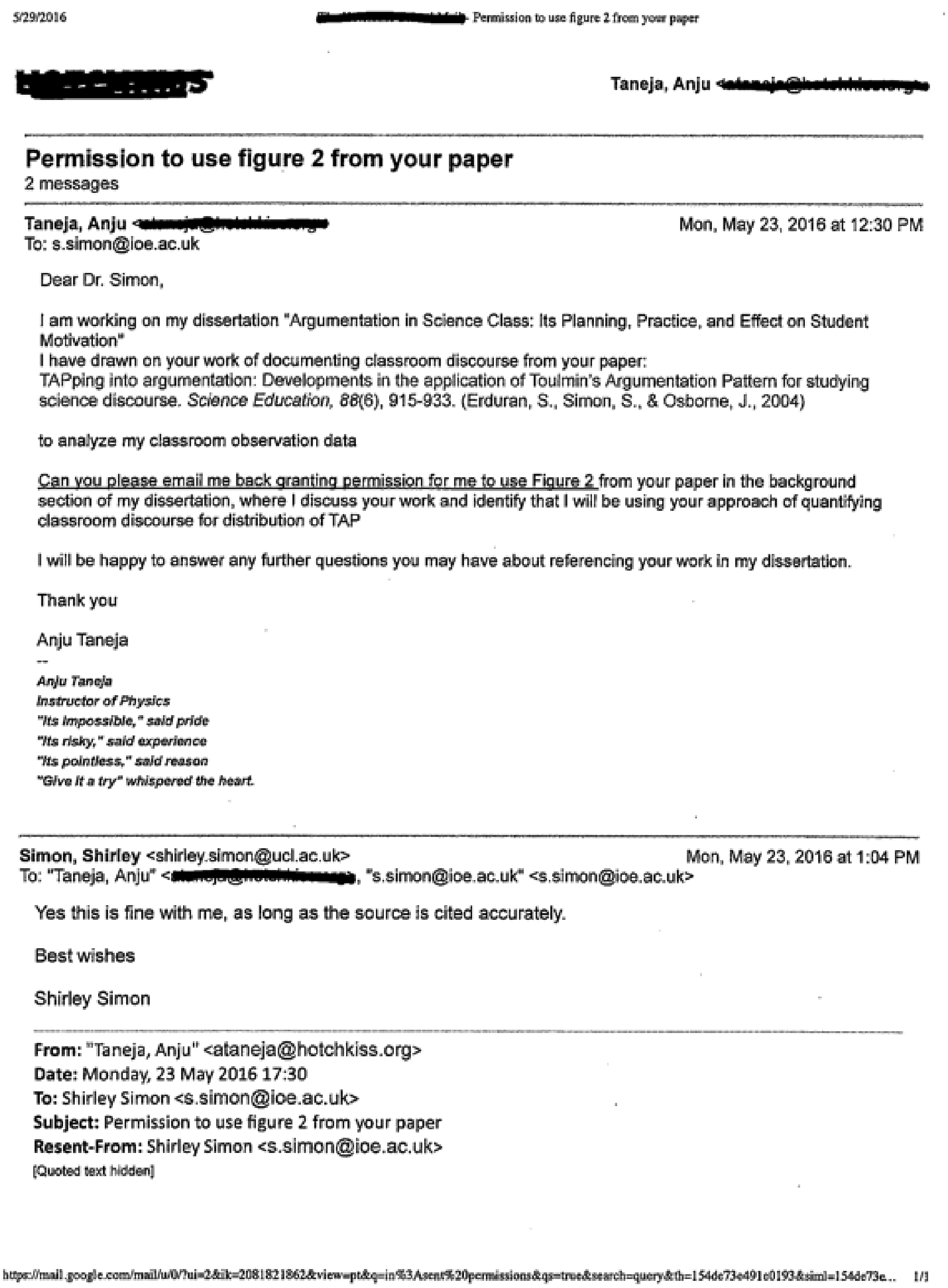
Dear Anju

yes, you have my permission to use that figure in your dissertation. Good luck and thanks for your interest in our work.

Best
[Quoted text hidden]
--
Sidney D'Mello
Associate Professor
Department of Computer Science
Department of Psychology
University of Notre Dame
Notre Dame, IN 46556
Phone:574-631-8322
http://www.nd.edu/~sdmello

https://mail.google.com/mail/u/0/?ui=2&ik=2081821862&view=pt&q=in%3Asent%20permissions&qs=true&search=query&th=154f40165bde53e6&siml=154f40165... 1/2

Appendix H 2: Permission to use Figure



5/29/2016 [redacted] Permission to use figure 2 from your paper

[redacted]

Taneja, Anju <[redacted]

Permission to use figure 2 from your paper

2 messages

Taneja, Anju <[redacted] Mon, May 23, 2016 at 12:30 PM

To: s.simon@ioe.ac.uk

Dear Dr. Simon,

I am working on my dissertation "Argumentation in Science Class: Its Planning, Practice, and Effect on Student Motivation"
I have drawn on your work of documenting classroom discourse from your paper:
TAPping into argumentation: Developments in the application of Toulmin's Argumentation Pattern for studying science discourse. *Science Education, 88*(6), 915-933. (Erduran, S., Simon, S., & Osborne, J., 2004)

to analyze my classroom observation data

Can you please email me back granting permission for me to use Figure 2 from your paper in the background section of my dissertation, where I discuss your work and identify that I will be using your approach of quantifying classroom discourse for distribution of TAP

I will be happy to answer any further questions you may have about referencing your work in my dissertation.

Thank you

Anju Taneja

--

Anju Taneja
Instructor of Physics
"Its impossible," said pride
"Its risky," said experience
"Its pointless," said reason
"Give it a try" whispered the heart.

Simon, Shirley <shirley.simon@ucl.ac.uk> Mon, May 23, 2016 at 1:04 PM

To: "Taneja, Anju" <[redacted], "s.simon@ioe.ac.uk" <s.simon@ioe.ac.uk>

Yes this is fine with me, as long as the source is cited accurately.

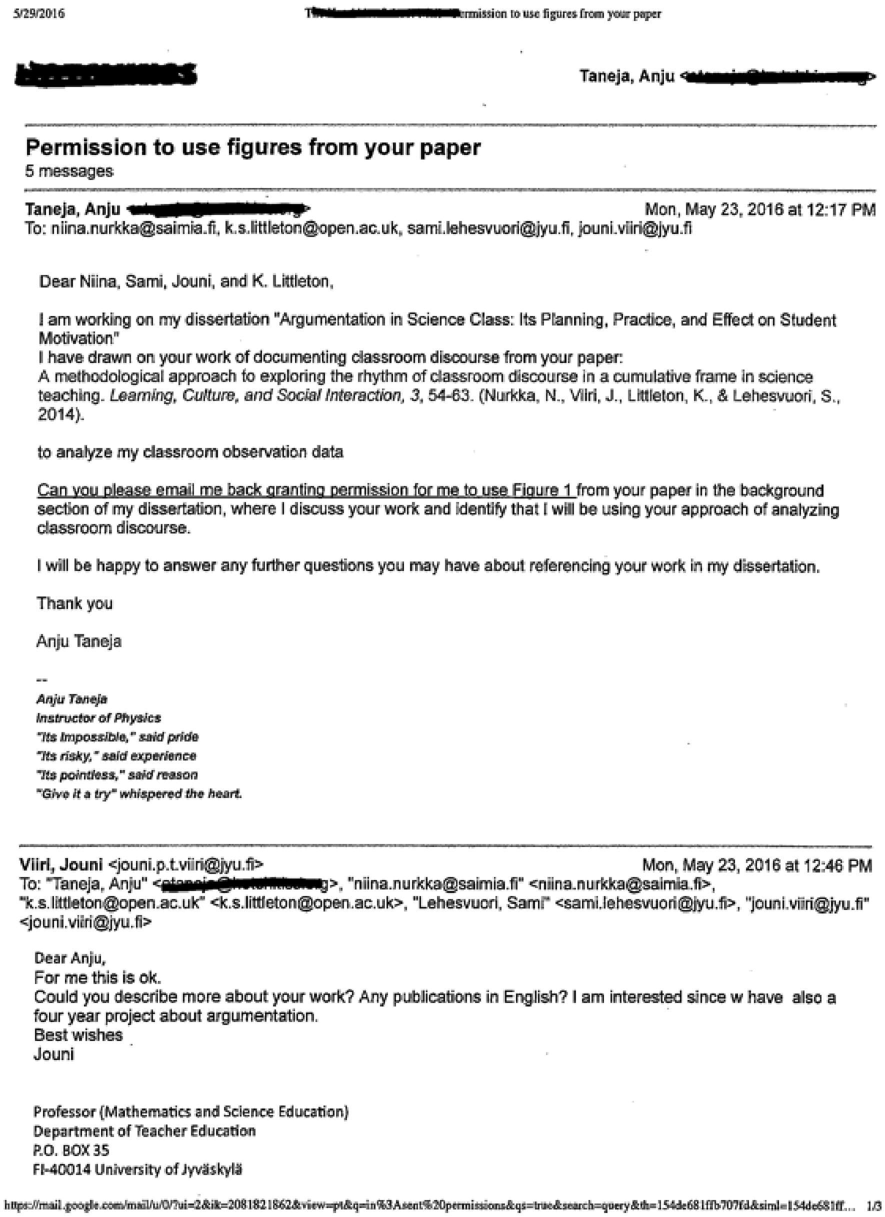
Best wishes

Shirley Simon

From: "Taneja, Anju" <ataneja@hotchkiss.org>
Date: Monday, 23 May 2016 17:30
To: Shirley Simon <s.simon@ioe.ac.uk>
Subject: Permission to use figure 2 from your paper
Resent-From: Shirley Simon <s.simon@ioe.ac.uk>
[Quoted text hidden]

https://mail.google.com/mail/u/0/?ui=2&ik=2081821862&view=pt&q=in%3Asent%20permissions&qs=true&search=query&th=154de73e491c0193&siml=154de73e... 1/1

Appendix H 3: Permission to use Figure



5/29/2016 T[redacted]ermission to use figures from your paper

[redacted] Taneja, Anju <[redacted]>

Permission to use figures from your paper
5 messages

Taneja, Anju <[redacted]> Mon, May 23, 2016 at 12:17 PM
To: niina.nurkka@saimia.fi, k.s.littleton@open.ac.uk, sami.lehesvuori@jyu.fi, jouni.viiri@jyu.fi

Dear Niina, Sami, Jouni, and K. Littleton,

I am working on my dissertation "Argumentation in Science Class: Its Planning, Practice, and Effect on Student Motivation"
I have drawn on your work of documenting classroom discourse from your paper:
A methodological approach to exploring the rhythm of classroom discourse in a cumulative frame in science teaching. *Learning, Culture, and Social Interaction, 3*, 54-63. (Nurkka, N., Viiri, J., Littleton, K., & Lehesvuori, S., 2014).

to analyze my classroom observation data

Can you please email me back granting permission for me to use Figure 1 from your paper in the background section of my dissertation, where I discuss your work and identify that I will be using your approach of analyzing classroom discourse.

I will be happy to answer any further questions you may have about referencing your work in my dissertation.

Thank you

Anju Taneja

--
Anju Taneja
Instructor of Physics
"Its Impossible," said pride
"Its risky," said experience
"Its pointless," said reason
"Give it a try" whispered the heart.

Viiri, Jouni <jouni.p.t.viiri@jyu.fi> Mon, May 23, 2016 at 12:46 PM
To: "Taneja, Anju" <[redacted]>, "niina.nurkka@saimia.fi" <niina.nurkka@saimia.fi>, "k.s.littleton@open.ac.uk" <k.s.littleton@open.ac.uk>, "Lehesvuori, Sami" <sami.lehesvuori@jyu.fi>, "jouni.viiri@jyu.fi" <jouni.viiri@jyu.fi>

Dear Anju,
For me this is ok.
Could you describe more about your work? Any publications in English? I am interested since w have also a four year project about argumentation.
Best wishes
Jouni

Professor (Mathematics and Science Education)
Department of Teacher Education
P.O. BOX 35
FI-40014 University of Jyväskylä

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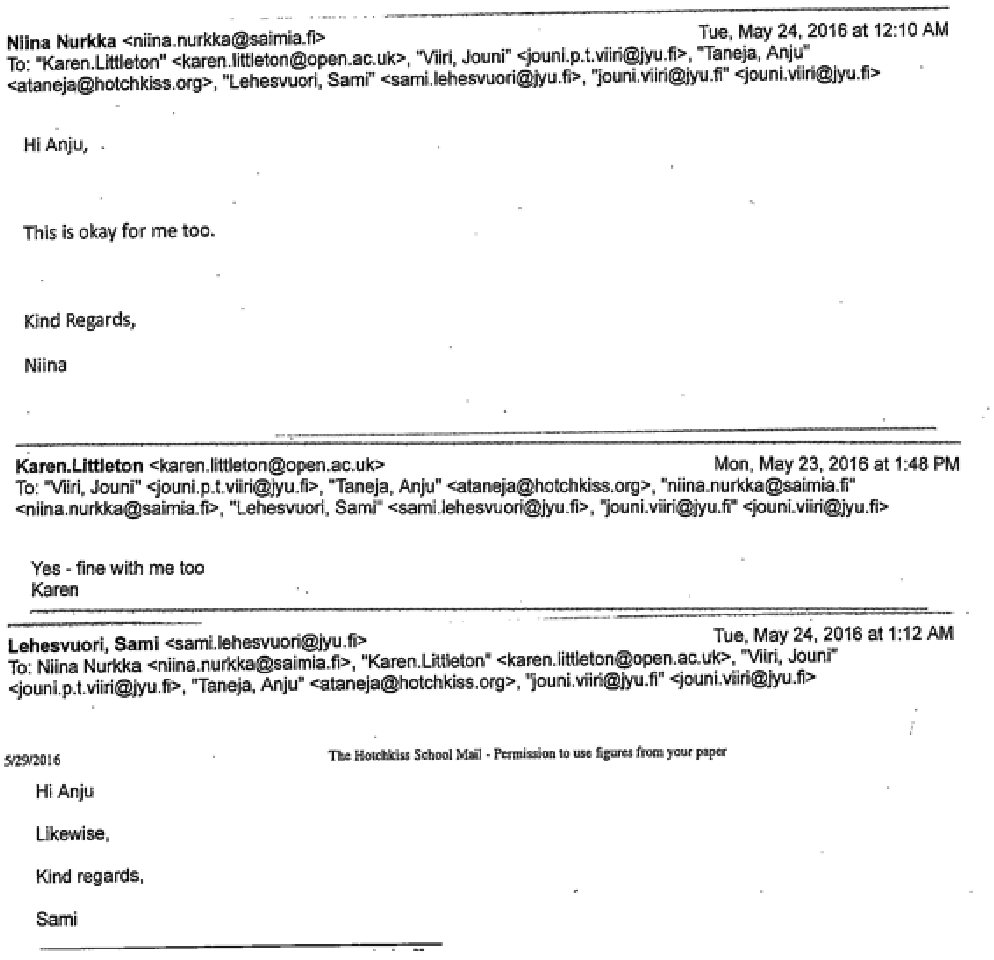


Niina Nurkka <niina.nurkka@saimia.fi> Tue, May 24, 2016 at 12:10 AM
To: "Karen.Littleton" <karen.littleton@open.ac.uk>, "Viiri, Jouni" <jouni.p.t.viiri@jyu.fi>, "Taneja, Anju" <ataneja@hotchkiss.org>, "Lehesvuori, Sami" <sami.lehesvuori@jyu.fi>, "jouni.viiri@jyu.fi" <jouni.viiri@jyu.fi>

Hi Anju,

This is okay for me too.

Kind Regards,

Niina

Karen.Littleton <karen.littleton@open.ac.uk> Mon, May 23, 2016 at 1:48 PM
To: "Viiri, Jouni" <jouni.p.t.viiri@jyu.fi>, "Taneja, Anju" <ataneja@hotchkiss.org>, "niina.nurkka@saimia.fi" <niina.nurkka@saimia.fi>, "Lehesvuori, Sami" <sami.lehesvuori@jyu.fi>, "jouni.viiri@jyu.fi" <jouni.viiri@jyu.fi>

Yes - fine with me too
Karen

Lehesvuori, Sami <sami.lehesvuori@jyu.fi> Tue, May 24, 2016 at 1:12 AM
To: Niina Nurkka <niina.nurkka@saimia.fi>, "Karen.Littleton" <karen.littleton@open.ac.uk>, "Viiri, Jouni" <jouni.p.t.viiri@jyu.fi>, "Taneja, Anju" <ataneja@hotchkiss.org>, "jouni.viiri@jyu.fi" <jouni.viiri@jyu.fi>

5/29/2016 The Hotchkiss School Mail - Permission to use figures from your paper

Hi Anju

Likewise,

Kind regards,

Sami

Appendix H 4: Permission to use Figure

6/1/2016 [redacted]

[redacted]

Taneja, Anju [redacted]

(no subject)

Wiley Global Permissions <permissions@wiley.com> Wed, Jun 1, 2016 at 7:39 AM
To: "Taneja, Anju" [redacted]

Dear Anju Taneja

Thank you for your request.

Permission is granted for you to use the material requested for your thesis/dissertation subject to the usual acknowledgements (author, title of material, title of book/journal, ourselves as publisher) and on the understanding that you will reapply for permission if you wish to distribute or publish your thesis/dissertation commercially. You must also duplicate the copyright notice that appears in the Wiley publication in your use of the Material; this can be found on the copyright page if the material is a book or within the article if it is a journal.

Permission is granted solely for use in conjunction with the thesis, and the material may not be posted online separately.

Any third party material is expressly excluded from this permission. If any of the material you wish to use appears within our work with credit to another source, authorisation from that source must be obtained.

Best wishes,

Aimee Masheter

Permissions Assistant

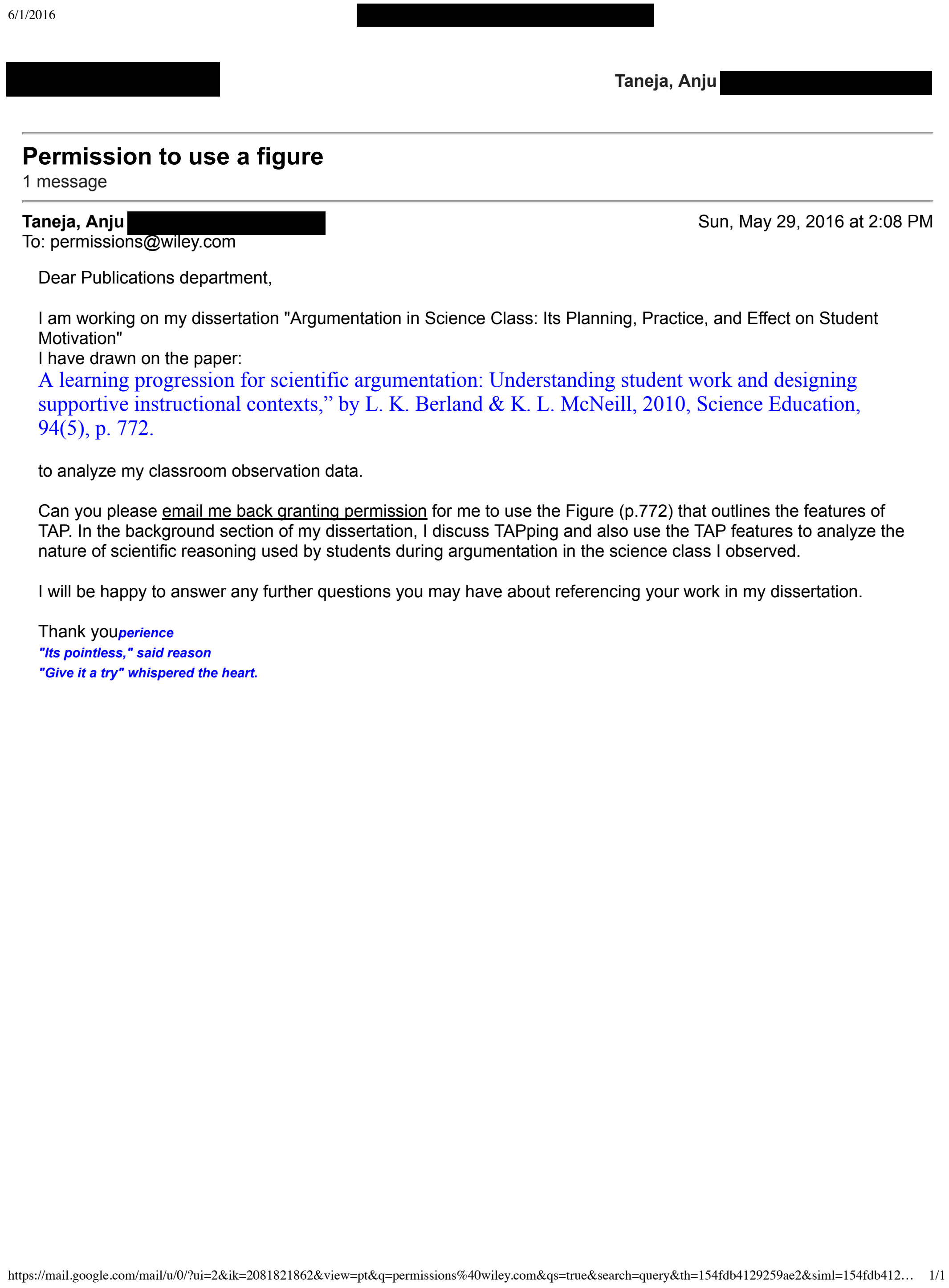
John Wiley & Sons Ltd

The Atrium

Southern Gate, Chichester

West Sussex, PO19 8SQ

UK



[redacted]

Taneja, Anju [redacted]

Permission to use a figure

1 message

Taneja, Anju [redacted]
To: permissions@wiley.com

Sun, May 29, 2016 at 2:08 PM

Dear Publications department,

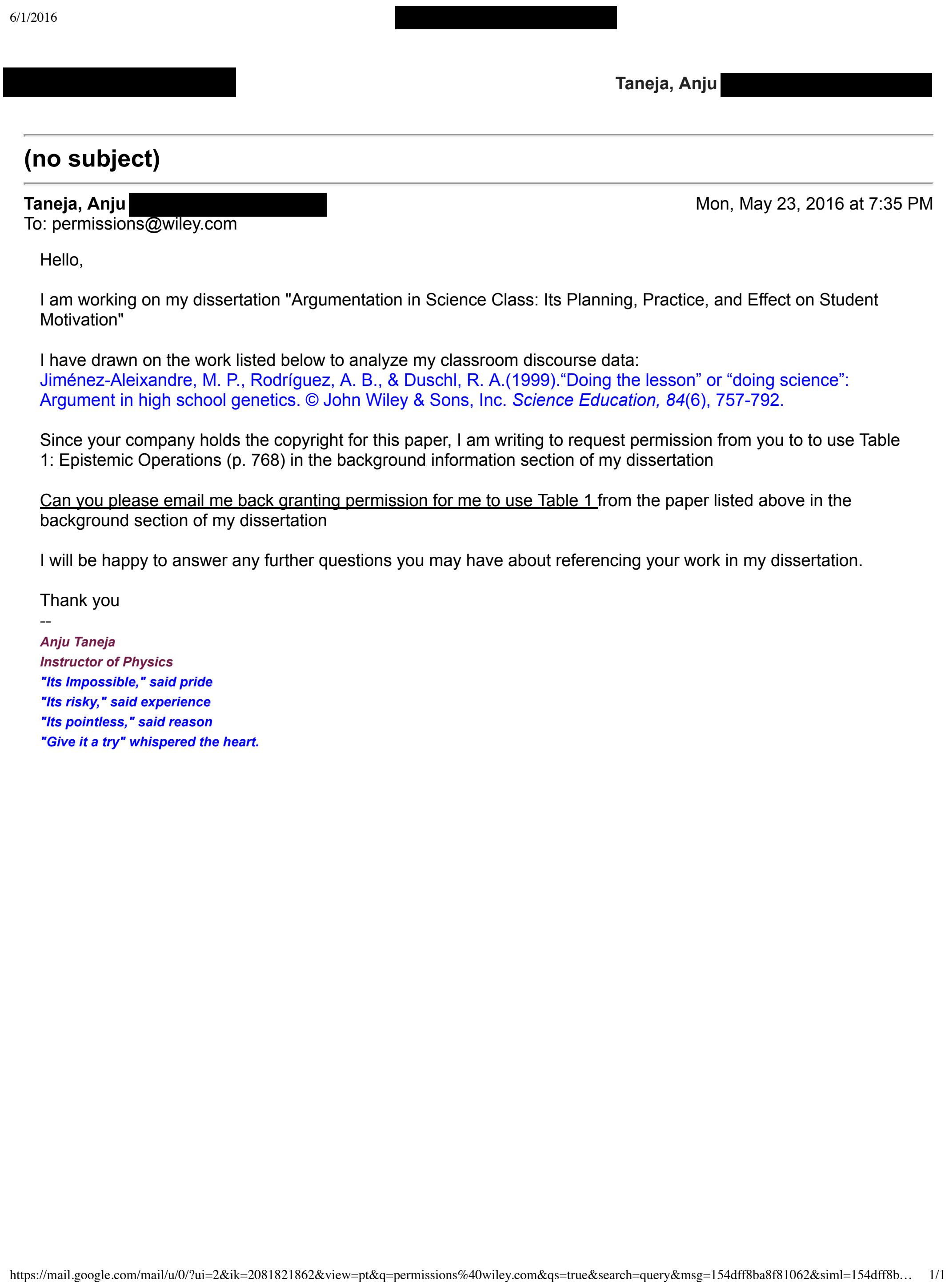
I am working on my dissertation "Argumentation in Science Class: Its Planning, Practice, and Effect on Student Motivation"
I have drawn on the paper:
A learning progression for scientific argumentation: Understanding student work and designing supportive instructional contexts," by L. K. Berland & K. L. McNeill, 2010, Science Education, 94(5), p. 772.

to analyze my classroom observation data.

Can you please email me back granting permission for me to use the Figure (p.772) that outlines the features of TAP. In the background section of my dissertation, I discuss TAPping and also use the TAP features to analyze the nature of scientific reasoning used by students during argumentation in the science class I observed.

I will be happy to answer any further questions you may have about referencing your work in my dissertation.

Thank you*perience*
"Its pointless," said reason
"Give it a try" whispered the heart.



[redacted] **Taneja, Anju** [redacted]

(no subject)

Taneja, Anju [redacted] Mon, May 23, 2016 at 7:35 PM
To: permissions@wiley.com

Hello,

I am working on my dissertation "Argumentation in Science Class: Its Planning, Practice, and Effect on Student Motivation"

I have drawn on the work listed below to analyze my classroom discourse data:
Jiménez-Aleixandre, M. P., Rodríguez, A. B., & Duschl, R. A.(1999).“Doing the lesson” or “doing science”: Argument in high school genetics. © John Wiley & Sons, Inc. *Science Education, 84*(6), 757-792.

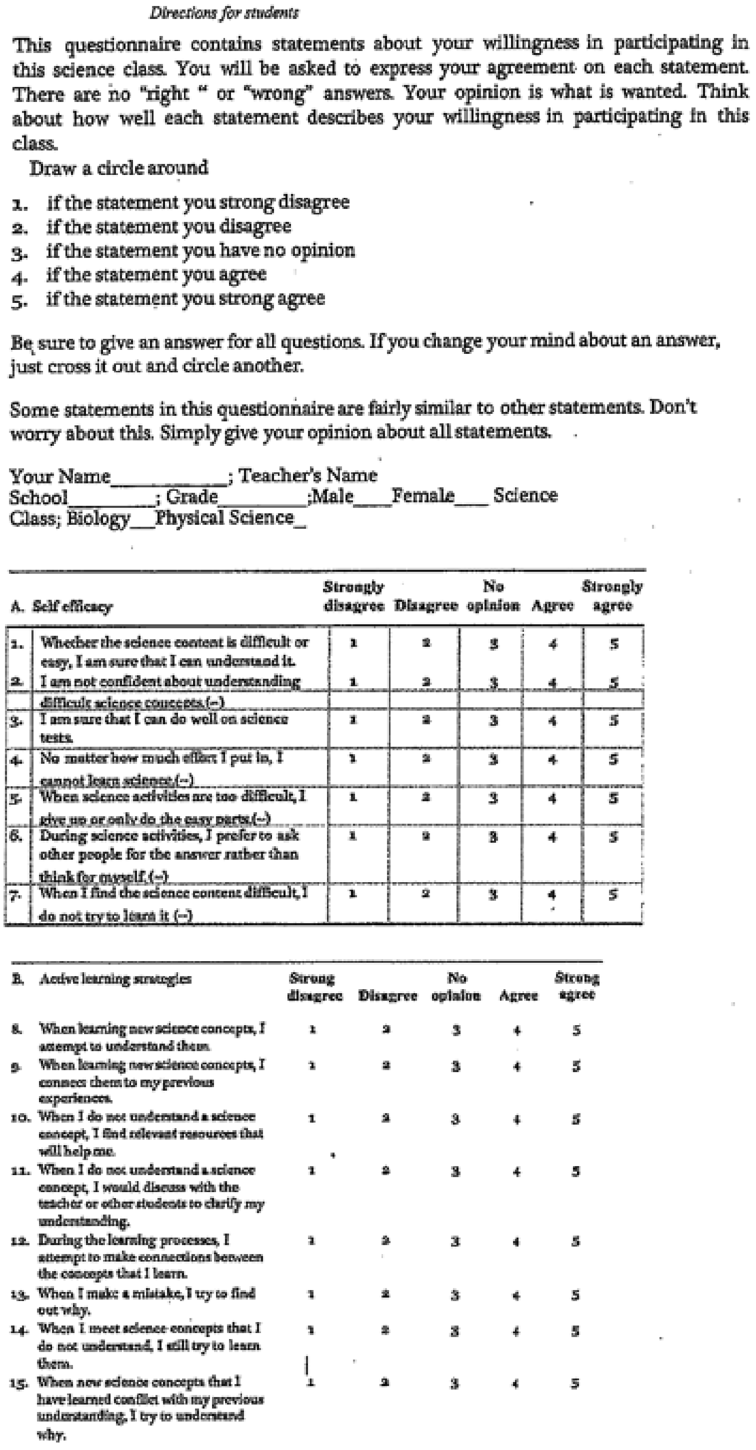
Since your company holds the copyright for this paper, I am writing to request permission from you to to use Table 1: Epistemic Operations (p. 768) in the background information section of my dissertation

Can you please email me back granting permission for me to use Table 1 from the paper listed above in the background section of my dissertation

I will be happy to answer any further questions you may have about referencing your work in my dissertation.

Thank you
--
Anju Taneja
Instructor of Physics
"Its Impossible," said pride
"Its risky," said experience
"Its pointless," said reason
"Give it a try" whispered the heart.

Appendix I: Student Motivation Towards Science Learning Instrument



Directions for students

This questionnaire contains statements about your willingness in participating in this science class. You will be asked to express your agreement on each statement. There are no "right " or "wrong" answers. Your opinion is what is wanted. Think about how well each statement describes your willingness in participating in this class.

Draw a circle around

1. if the statement you strong disagree
2. if the statement you disagree
3. if the statement you have no opinion
4. if the statement you agree
5. if the statement you strong agree

Be sure to give an answer for all questions. If you change your mind about an answer, just cross it out and circle another.

Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about all statements.

Your Name___________; Teacher's Name
School_________; Grade_________;Male___Female___ Science
Class; Biology__Physical Science_

	A. Self efficacy	Strongly disagree	Disagree	No opinion	Agree	Strongly agree
1.	Whether the science content is difficult or easy, I am sure that I can understand it.	1	2	3	4	5
2.	I am not confident about understanding difficult science concepts.(–)	1	2	3	4	5
3.	I am sure that I can do well on science tests.	1	2	3	4	5
4.	No matter how much effort I put in, I cannot learn science.(–)	1	2	3	4	5
5.	When science activities are too difficult, I give up or only do the easy parts.(–)	1	2	3	4	5
6.	During science activities, I prefer to ask other people for the answer rather than think for myself.(–)	1	2	3	4	5
7.	When I find the science content difficult, I do not try to learn it (–)	1	2	3	4	5

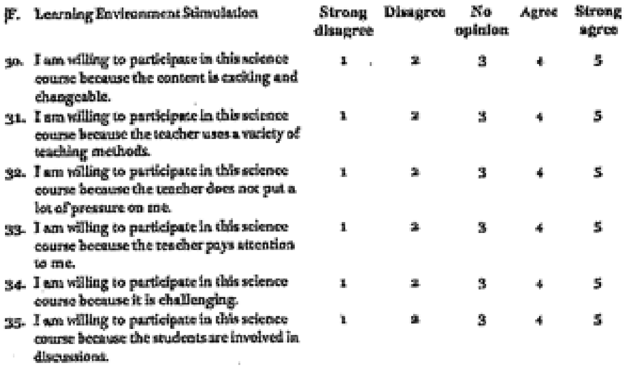
B.	Active learning strategies	Strong disagree	Disagree	No opinion	Agree	Strong agree
8.	When learning new science concepts, I attempt to understand them.	1	2	3	4	5
9.	When learning new science concepts, I connect them to my previous experiences.	1	2	3	4	5
10.	When I do not understand a science concept, I find relevant resources that will help me.	1	2	3	4	5
11.	When I do not understand a science concept, I would discuss with the teacher or other students to clarify my understanding.	1	2	3	4	5
12.	During the learning processes, I attempt to make connections between the concepts that I learn.	1	2	3	4	5
13.	When I make a mistake, I try to find out why.	1	2	3	4	5
14.	When I meet science concepts that I do not understand, I still try to learn them.	1	2	3	4	5
15.	When new science concepts that I have learned conflict with my previous understanding, I try to understand why.	1	2	3	4	5

[redacted]

C. Science Learning Value	Strong disagree	Disagree	No opinion	Agree	Strong agree
16. I think that learning science is important because I can use it in my daily life.	1	2	3	4	5
17. I think that learning science is important because it stimulates my thinking.	1	2	3	4	5
18. In science, I think that it is important to learn to solve problems.	1	2	3	4	5
19. In science, I think it is important to participate in inquiry activities.	1	2	3	4	5
20. It is important to have the opportunity to satisfy my own curiosity when learning science.	1	2	3	4	5

D. Performance Goal	Strong disagree	Disagree	No opinion	Agree	Strong agree
21. I participate in science courses to get a good grade. (–)	1	2	3	4	5
22. I participate in science courses to perform better than other students. (–)	1	2	3	4	5
23. I participate in science courses so that other students think that I'm smart.(–)	1	2	3	4	5
24. I participate in science courses so that the teacher pays attention to me.(–)	1	2	3	4	5

E. Achievement Goal	Strong disagree	Disagree	No opinion	Agree	Strong agree
25. During a science course, I feel most fulfilled when I attain a good score in a test.	1	2	3	4	5
26. I feel most fulfilled when I feel confident about the content in a science course.	1	2	3	4	5
27. During a science course, I feel most fulfilled when I am able to solve a difficult problem.	1	2	3	4	5
28. During a science course, I feel most fulfilled when the teacher accepts my ideas.	1	2	3	4	5
29. During a science course, I feel most fulfilled when other students accept my ideas.	1	2	3	4	5



F. Learning Environment Stimulation	Strong disagree	Disagree	No opinion	Agree	Strong agree
30. I am willing to participate in this science course because the content is exciting and changeable.	1	2	3	4	5
31. I am willing to participate in this science course because the teacher uses a variety of teaching methods.	1	2	3	4	5
32. I am willing to participate in this science course because the teacher does not put a lot of pressure on me.	1	2	3	4	5
33. I am willing to participate in this science course because the teacher pays attention to me.	1	2	3	4	5
34. I am willing to participate in this science course because it is challenging.	1	2	3	4	5
35. I am willing to participate in this science course because the students are involved in discussions.	1	2	3	4	5

Appendix J: Physics Worksheet Questions

Question 1:

Akhtar, Kiran, and Rahul were riding in a motorcar that was moving with a high velocity on an expressway when an insect hit the windshield and got stuck on the windscreen. Akhtar and Kiran started pondering over the situation.

A. Kiran suggested that the insect suffered a greater change in momentum as compared to the change in momentum of the motorcar because the change in velocity of the insect was much more than that of the motorcar.
B. Akhtar said that since the motorcar was moving with a larger velocity, it exerted a larger force on the insect.
C. Rahul while putting an entirely new explanation said that both the motorcar and the insect experienced the same force and a change in their momentum.

Question 2:

Study the illustration of the diver. Then indicate whether the following statements are true or false. If the statement is false, change the word(s) in **bold** to make it true. Explain your changes.

(i) After the diver jumps forward from the diving board, the force of gravity will accelerate the diver **parallel** to the direction of motion.
(ii) When the diver hits the water, the force of the water against her body can stop it **faster** than the pull of gravity accelerated it.
(iii) If the diver doesn’t have the correct form when she enters the water, the force of the water can **accelerate** her speed.
(iv) When the diver enters the water, the force of the water is **opposite** to the velocity of the diver.
(v) **Momentum** prevents the diver from moving in a straight line once she jumps from the platform.

Question 3:

Discuss the nature of the forces acting on the ball during its one up and down motion as shown in the diagram.