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Modeling to Promote Academically Productive Discourse in Science Classrooms--A New Teacher Study

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Modeling to Promote Academically Productive Discourse in Science Classrooms—

A New Teacher Study

A dissertation submitted in partial satisfaction of the requirements for the degree of Doctor of Education

by

Lynn Kim-John

2015
ABSTRACT OF THE DISSERTATION

Modeling to Promote Academically Productive Discourse in Science Classrooms—
A New Teacher Study

by

Lynn Kim-John

Doctor of Education

University of California, Los Angeles, 2015

Professor Diane Durkin, Co-Chair

Professor William Sandoval, Co-Chair

As our nation continues to transition into the Next Generation Science Standards, it will be important to take a closer look at teacher preparation programs. In particular, the language demands of the NGSS will require that teachers integrate approaches to open up opportunities for student to engage in productive, student-centered discourse. This study follows ten teachers into their first year of teaching to observe the impacts of a secondary science methods course focused on opening up student discourse through the a model-based pedagogical framework. Findings
illustrate first-year teachers’ perspectives on the goal of student talk, as well as their perspectives on how models and modeling activities support student talk. The findings from this study offers recommendations on how teachers preparation programs might revise their programs to better align to the language demands of the Next Generation Science Standards.
The dissertation of Lynn Kim-John is approved.

James W. Stigler

Jose-Felipe Martinez-Fernandez

Professor Diane Durkin, Co-Chair

Professor William Sandoval, Co-Chair

University of California, Los Angeles

2015
DEDICATION PAGE

To my joy and inspirations:

Nicholas and Jeremy John,
the two amazing boys I have the privilege of being “mommy” of

&

Riley, Katelyn, Colin and Hannah Chong,
the children I am blessed to be “auntie” of:

“You may encounter many defeats, but you must not be defeated. In fact, it may be necessary to encounter the defeats, so you can know who you are, what you can rise from, how you can still come out of it.”

--Maya Angelou
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CHAPTER 1: INTRODUCTION

Over the last decade, researchers have increasingly emphasized the development of students’ language and communication skills when learning about science (National Governors Association Center for Best Practices, Council of Chief State School Officers [CCSSO], 2010; National Research Council [NRC], 1996, 2000; Next Generation Science Standards [Next Generation] Lead States, 2013). These experts continue to prioritize higher-order thinking skills over a more traditional view of learning science as a body of knowledge (McNeill & Knight, 2013). This shift is changing the landscape of K-12 science education.

In 1996, the National Science Education Standards defined “science literacy” as the ability to engage intelligently in public discourse (National Science Education Standards, March, 1996). The focus on discourse led to the integration of student communication skills, such as argumentation, into science standards (NRC, 1996). Today, student communication has an even larger presence in state standards for science. The Common Core State Standards (Common Core) explicitly highlight speaking as one of the “college and career-ready anchor standards” which all students should develop in order to collaborate, communicate, and present ideas persuasively (CCSSO, 2010). Similarly, the newly endorsed Next Generation Science Standards have integrated key communication-based practices throughout the K-12 learning progression. Students are expected to construct explanations, engage in argumentation, and communicate information (NRC, 2012).

The emphasis on language in learning science is based on the belief that individuals’ ability to undertake critical collaborative argumentation is an essential skill for success in the future (Osborne, 2010). Moreover, being able to engage in scientific discourse is not only viewed
as a goal for science literacy, but one for effective citizenship (McNeill & Knight, 2013; Sadler, 2006). In our rapidly changing world, scientific literacy aligns with the reasoning skills necessary to effectively engage as consumers and voters (Rychen & Salganik, 2003).

**Benefits of Student Discourse**

The emphasis on language in learning is based on research that highlights the benefits of student discourse. Studies show that students who experience discourse as part of learning science outperform those who do not have a chance to engage in discussion (Asterhan & Schwarz, 2007; Mercer, Dawes, Wegerif, & Sams, 2004; Zohar & Nemet, 2002). In a meta-analysis of fourteen classes taught using traditional methods, Hake (1998) showed that students achieved an average gain of only 25% between their pre- and post-test scores. In contrast, when lecturers paused and asked students to discuss the concept presented in pairs or small groups (i.e., three or four students), students achieved an average gain of 48% (Hake, 1998). Studies have shown that students benefit from student-centered discourse, even outperforming students who learn through hands-on experience (Chi, 2009).

**Problem Statement**

Despite what we know about the benefits of student discourse, it is virtually absent from today’s science classrooms (Newton, Driver, & Osborne, 1999; Sadler, 2006). In a small classroom observation study conducted by Sadler (2006), it was found that in 11 out of 14 science classrooms discourse was absent from the learning experience. In fact, in the small school district he observed, Lemke (1990) found that only 2% of all junior high school classrooms engaged students in discussion.

In classrooms that attempted discussions, teachers continued to be at the center of discussion (Driver, Newton, & Osborne, 2000; Duschl & Osborne, 2002; Sadler, 2006). Dillon
(1998) visited 27 classrooms across six schools and found that over 60% of the questions came from teachers, while only a small percent of questions were formulated by students. Tsui (1995) also found that “student talk” accounted for an average of less than 30% of the total talk in classrooms. Teachers continue to take up most of the talk time, leaving little time for student participation (Duschl & Osborne, 2002). Although class discussion dominated by teacher-led structure – which focuses on facts – does not help promote student reasoning (Duschl & Osborne, 2002; Osborne, 2010), classrooms continue to rely on this authoritative mode of discourse (Scott, 1998).

**Modeling to Promote Student-Centered Talk**

While the Common Core and Next Generation Science Standards emphasize the importance of student-centered discourse in learning science, research indicates an absence of discourse opportunities in the classroom. Hence, professional learning opportunities, as well as teacher preparation, will have to support teachers in opening up opportunities for student talk as they transition into the new standards.

Studies show that model-based activities are an effective approach to increasing student-centered discourse in the science classroom (Campbell, Oh, & Neilson, 2012; Windschitl, Thompson, & Braaten, 2008). Michaels, O’Connor, and Resnick (2008) and Campbell et al., (2012) studied conversation patterns among students engaged in model-based science instruction. In both studies, students were engaged in deep authentic dialogue about science with their peers, resembling the process scientists engage in. Windschitl et al., (2008) also studied a middle school teacher’s model-based earth science lesson and found that students engaged in rich conversations directly linked to the models they created, and subsequently revised, in order to reflect learning. Similarly, Campbell et al., (2012) studied a high school physics class to
examine the discourse pattern among students engaged in a model-based science and found that students negotiated and revised their understanding of physics by engaging in conversations with peers using and talking about the models they developed in order to explain their thinking.

**Accountable Talk**

Studies also highlight the importance of the teacher's role in fostering effective classroom conversations (Chin 2006; Webb, 2009). The work of McNeill and Pimentel (2010) and Chin (2006) both highlight the importance of teacher moves and questioning in order to open up opportunities for student-centered discourse. Upon analyzing classroom transcripts, McNeill and Pimentel (2010) found that teachers’ use of open-ended questions plays a key role in supporting student argumentation. Teachers have the ability to help students provide evidence and reasoning to support claims, and are able to encourage dialogic interactions between students by using effective questioning strategies.

Similarly, Michaels et al., (2008) found that teachers’ use of questions calling for elaborated response by students produced academically productive and rigorous classroom discourse. When teachers press students to develop their explanations, to challenge their thoughts, and to question others, teachers are able to promote a student-centered, discourse-rich classroom. Over 20 years’ of observing effective classroom conversations, researchers have identified what it takes to lay the foundation for productive classroom discourse, leading to a set of guidelines now called Accountable Talk (Michaels et al., 2008). The Accountable Talk Protocol highlights four goals for academically productive talk and nine teacher moves to promote a student-centered discourse (Michaels et al., 2008).

Recent studies show that classroom subject matter guided by Accountable Talk leads to increases in student outcomes (Michaels et al., 2008). After two years of integrating Accountable
Talk strategies, students scored the highest “probability of giftedness” on a test for math abilities and 82% of these students scored at “advanced” or ”proficient” on the Massachusetts State Exam (Anderson, Chapin, & O’Connor, 2011).

**Implications for Teacher Training**

The absence of discourse opportunities in classrooms requires a closer look at teacher training, particularly at teacher preparation. Studies indicate a lack of discourse in classrooms because teachers lack knowledge about how to integrate discussion into their curricula (McNeill & Knight, 2013). The Common Core and Next Generation Science Standards will have implications for teacher preparation. Teachers need pedagogical strategies to learn how to integrate discussions into classroom learning experiences (Osborne, Erduran, & Simon, 2004; Thompson, Windschitl, & Braaten, 2013). This study will look at the impact of a teacher preparation program focused on promoting academically productive discourse among students as an integral part of the science learning experience.

**The Project and Research Questions**

Because the use of models in science instruction has been shown to increase student-centered discourse in science classrooms (Campbell et al., 2012; Kawasaki, Herrenkohl, & Yeary, 2004; Windschitl et al., 2008), I examined a secondary science teacher education program that redesigned its Fall Secondary Science Methods Course to focus on modeling as an approach to promote academically productive talk, i.e., Accountable Talk (Michaels et al., 2008), as shown in Figure 1.
Figure 1: Framework for Secondary Science Methods Course

In order to understand how to better prepare teachers for the discourse demands of the Next Generation Science Standards, this study examined the integration of modeling into instruction as an approach to promote student-centered discourse, seeking to answer the following research questions:

1) *What do first-year teachers say about the goal of student talk?*

2) *How do first-year teachers believe modeling supports student talk?*

3) *How are these perceptions about modeling to support student talk realized in the classroom?*

**Research Site**

This study took place in a teacher education program at a public state university. The site offered a graduate program specializing in urban teacher preparation in the form of a two-year intensive Masters of Education (M.Ed.) program in social justice in urban communities. The program provided an opportunity for qualified candidates to obtain both a California teaching credential in science and an M.Ed. in a combined, full-time, two-year program which maintains
strict academic and professional expectations and practices.

During the first year, students completed coursework and began student teaching in the program’s partnership schools in order to meet California’s teacher credentialing requirements. Second-year students, or “residents,” assumed paid teaching positions in a partner school district and completed an inquiry-based research project in which they examined and reflected on their own classroom practices in order to complete their M.Ed. requirements.

**Design**

This study utilized a qualitative research design. A qualitative design led to the thick and rich description necessary to understand how teachers perceive and use models to promote classroom conversations (Creswell 1994). Lesson plans provided insight into when teachers planned to integrate modeling in order to promote *student-centered talk*, which helped to schedule the classroom observations. Thereafter, classroom observations provided the detailed description and explanation (Maxwell 2004; Patton 1980; Yin 1994) about how teachers and students used models to engage in productive classroom talk. Finally, the data derived from interviews with teachers allowed inferences to be drawn about teachers’ perceptions of certain issues — in this case, student talk (Denzin & Lincoln, 1994; Marshall & Rossman 1999; Maxwell 2004).

**Public Engagement**

During the era of new national standards, pre-service teaching programs will be looking for best practices in preparing teachers. The findings from this study will provide insight into how to better prepare teachers for the Next Generation Science Standards.

At the conclusion of the study, there will be three levels of dissemination. Locally, I will share findings with the study site’s teacher education program faculty. Findings will highlight the
effectiveness of pedagogical preparation during pre-service years. It will illustrate, in detail, the strategies first-year teachers carried with them into their first year of teaching; it will also highlight with what issues teachers seemed to struggle. I will also share findings with local districts in order to provide insight into professional development for science teachers as the districts transition to the new national standards. Finally, findings will be shared with the California Science Project, a statewide network for science professional development, in order to inform both teacher preparation and teacher professional development.
CHAPTER 2: LITERATURE REVIEW

Students’ engagement in academic dialogue contributes to deeper learning – educators have long known that student talk lies at the center of learning (Gordon, 2009; Michaels et al., 2008). Moreover, effective communication is key to everyday citizenry and success in the workforce (Bybee, 1993; Hyslop, 2010; Roth & Désautels, 2004). Yet, research in K-12 classrooms indicates that student-centered discourse is absent from classrooms (Alozie, Moje, & Krajcik, 2009; Lemke, 1990; Nassaji & Wells, 2000; Newton et al., 1999).

During the last decade, school systems have been bound by the No Child Left Behind accountability system (No Child Left Behind Act, 2002). As a result, classroom instruction has been dominated by teacher-centered instruction, leaving little room for student-to-student interactions (Marx & Harris, 2006; Schoen & Fusarelli, 2008). With the Common Core and Next Generation science standards come new expectations for math, English and science: student-centered discourse is now a large part of the K-12 learning progression (National Governors Association Center for Best Practices Initiative [NGA-BP Initiative], 2012; NRC, 2012).

Today’s apparent lack of student-to-student discourse opportunities in classrooms (Alozie et al., 2009; Lemke, 1990; Nassaji & Wells, 2000; Newton et al., 1999) requires a shift in teacher practice (NRC, 2012); NGA-BP Initiative, 2012). Classroom culture will have to move from test-based results to problem-based investigations requiring student-to-student interaction (Porter, McMaken, Hwang, & Yang, 2011). This shift will have implications for teacher preparation programs.

This literature synthesis explores those research-based practices found to increase opportunities for student-centered discourse in K-12 science classrooms. I begin by characterizing “discourse,” describe the research-based intersection between language and
learning, and how the new national standards reflect these findings. After describing the state of discourse in classrooms, I explore implications for teacher preparation programs. I link pre-service teacher needs with an overview of those research-based approaches shown to have increased student talk in the classroom. Finally, I end with a description of a pre-service course designed and aligned to recent research recommendations to enhance student talk.

What is Student-Centered Discourse?

The recent publication Taking Science To School (Duschl, Schweingruber, & Shouse, 2007) highlights elements of classroom instruction shown to support student learning. The report states that students benefit from participation in discipline-specific activity and talk with peers. Mortimer and Scott (Erduran, 2005), however, define “discourse” as more than student talk: it is an interactive dialogue characterized by teacher and student exploring ideas, posing genuine questions and offering, listening to and working on different points of view. Moreover, recent scholarship characterizes classroom discourse as authentic student-centered exchange, such as generating evidence-based explanations, represent thinking to others, critiquing the argument of others, and questioning of peers to refine one’s own thinking (Berland & Hammer, 2012; Furtak, Hardy, Beinbrech, Shavelson, & Shemwell, 2010; Smart & Marshall, 2013).

Research has also examined the teacher’s role in promoting discourse. Recommendations from research call on teachers to mediate academic conversations by opening up opportunities within curriculum for student-centered interaction (Chin, 2007; Smart & Marshall, 2013). It calls on teachers to facilitate a community of learners wherein students are speaking, listening, and engaging in reasoning with one another.
Importance of Student-Centered Discourse

Many studies highlight the link between the language of and the learning of science (Erduran, 2005; Gee & Green, 1998; Lemke, 1990; Michaels et al., 2008; Newton et al., 1999; Smart & Marshall, 2013). Lemke (1990) emphasizes language as “a system of resources for making meaning.” He delineates “talking science” and talking about science, and argues the importance of doing science through the medium of language.

Studies show that content-based discourse leads to a deeper understanding of science content. For example, when some high school students were explicitly taught how to use evidence to dialogue within small groups, these “experimental group” students scored an average of 73% on a genetics post-test, while control students, i.e., those not participating in the small group dialogues, only averaged 60% on the test (Zohar & Nemet, 2002). Similarly, and Striley (1996) studied the discourse of 10th grade science students during a lab experiment. They found that scientific argumentation, a type of science discourse, led to deeper content development. Howe and Tolmie (2003) also found that conceptual understanding in science was enhanced by children’s discussion of ideas during group work.

Context: A Shift Towards National Standards

The national content standards reflect the importance of student-centered discourse in learning science. Common Core and Next Generation science standards highlight student talk as a key strand through the K-12 learning progression (CCSS Officers 2010; NRC, 2012). This emphasis on student talk is different from the traditional state standards that teachers have grown accustomed to (Garet, Porter, Desimone, Birman, & Yoon, 2001; Porter et al., 2011).

The Common Core State Standards, anchored by a set of college and career ready standards, have a “speaking and listening” strand that spans the entire K-12 learning spectrum
(CCSSO, 2010). These standards state that students must have opportunities to take part in conversations—as part of a whole class, in small groups, and/or with a partner, with the expectation that students contribute to oral discussion and respond to peers. Specifically, these standards require students to “participate effectively in a range of conversations,” “express their own ideas clearly and persuasively,” “present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization,” and “adapt speech to a variety of contexts and communicative tasks” (CCSSO, 2010). The standards are discourse-heavy and markedly different from original state standards; particularly, they move the discourse from an authoritative model of discourse wherein teachers are the center of discussion to a more dialogic model of discussion in which students are the center of discussion.

In addition to the Common Core State Standards, science teachers are likewise accountable to the Next Generation Science Standards which also emphasize discourse as a part of the K-12 learning experience. The NRC (2012) identifies eight scientific practices that align to the work of scientists and should be included in K-12 science instruction:

1. Asking questions (for science) and defining problems (for engineering).
2. Developing and using models.
3. Planning and carrying out investigations.
4. Analyzing and interpreting data.
5. Using mathematics and computational thinking.
6. Constructing explanations (for science) and designing solutions (for engineering).
7. Engaging in argument from evidence.
8. Obtaining, evaluating, and communicating information.

Among these eight recommendations, four require students to take responsibility for classroom discourse. For example, Practice #1 requires students to ask questions of each other in order to guide classroom investigations (NRC, 2012, p. 56). Practice #6 is also aligned to student
discussion as it expects them to explain their ideas about scientific phenomena (p. 52), which inherently requires them to talk to one another. Similarly, Practice #7 expects students to engage in argumentative dialogue in order to defend or explain their thinking (p. 73) and Practice #8 asks students to communicate information publicly (p. 76).

State of Classroom Discourse Today

Despite research findings and standards that reflect the importance of student discourse, studies show that student-centered discourse opportunities are absent from K-12 classrooms (Cazden, 2001; Lemke, 1990). Instead, teacher-centered, authoritative dialogue is a dominant approach to instruction today (Alozie et al., 2009; Cazden, 2001; Smart & Marshall, 2013; van Zee, Iwasyk, Kurose, Simpson, & Wild, 2001). However, teacher-centered instruction leaves little room for the student-to-student interaction (Alozie et al., 2009; Cazden, 2001; Smart & Marshall, 2013; van Zee et al., 2001) called for by the new standards.

Lemke (1990) refers to teacher-centered classroom discussion as triadic dialogue, a common pattern of discourse called Initiation, Response, Evaluation (IRE) (Herrenkohl & Guerra, 1998; McNeill & Pimentel, 2010). Students grow accustomed to the pattern of the teacher initiating instruction with a question, students responding to the question, and teachers evaluating student responses. An IRE pattern of discourse is found in teacher-centered classrooms (Cazden, 2001; Nassaji & Wells, 2000) where the “pedagogy of telling” (Alozie et al., 2009; Scott, Mortimer, & Aguiar, 2006) is rampant and student dialogue is rare. Studies show that because students have become accustomed to teachers as bearers of knowledge, they learn to wait for them to provide the correct answer (Lemke, 1990; van Zee et al., 2001), leaving little room for student discussion. Recent studies and current standards argue for classrooms to
move from the triadic dialogue, also known as *authoritative discourse*, toward a more dialogic approach wherein students are engaged in discussion.

**Vision of K-12 Education**

...learning about science and engineering involves integration of the knowledge of scientific explanations (i.e., content knowledge) and the practices needed to engage in scientific inquiry and engineering design. Thus the Framework seeks to illustrate how knowledge and practice must be intertwined in designing learning experiences in K–12 science education.

—NRC, 2012

In addition to developing a culture of talk in the classroom, science education reformers also envision K-12 science programs that “mirror” the work of scientists. Reformers desire that students appreciate and learn science by participating in activities analogous to what scientists actually do. One of the shifts called for by the NRC in the *Framework for K-12 Science Education* is to teach “the interconnected nature of science as it is practiced and experienced in the real world.”

Although classrooms have progressed from Dewey's (1938) criticism of science education as “ready-made knowledge,” many researchers claim K-12 science education is far from the ideal of engaging students in science the way scientists work. Researchers suggest that teachers need to move away from hands-on activities that do not promote inquiry or content development (Windschitl, Thompson, & Braaten, 2008), and move toward inquiry that promotes reasoning and content deepening, thereby replicating the work of scientists (Passmore, Stewart, & Cartier, 2009).

Because models are so important in science, research indicates that students should be engaged in reasoning with and about models. Studies show that when students work with models, their engagement resembles the work of scientists (Campbell, Oh, & Neilson, 2012; Passmore & Svoboda, 2012; Passmore et al., 2009; Windschitl et al., 2008).
Scientists use models to guide investigations and engage in inquiries about the world (Campbell et al., 2012; Kenyon, Schwarz, & Hug, 2008; Passmore et al., 2009; Windschitl et al., 2008). They develop, use, assess, and revise models in order to solve problems or understand complex phenomena (Schwarz et al., 2009; Windschitl et al., 2008). As a result, the 2012 Framework for K-12 Science Education highlights the importance of students engaging in scientific practices because doing so “helps students understand how scientific knowledge develops” (NRC, 2012, p. 42).

**Defining Models and Model-Based Reasoning**

**Models**

A *model* is typically defined as a physical representation. For the purpose of this study, a *science model* is more than just that. Giere (1999) defines models as a “form of explanation.” Schwarz et al., (2009), as well as Lehrer & Schauble (2010), extend this idea by adding that models are “specialized representation[s] for explaining concepts and making predicting.” There is also a consensus that a science model is a form of reasoning that makes student thinking visible. For example, Lehrer & Schauble (2000) argue that models are a form of thinking “made public and inspectable.” Similarly, Windschitl, Thompson, Braaten, & Stroupe (2012) define models as “visible anchors” to form explanations. Harrison & Treagust's (2000) definition of a model is a nice synthesis of these ideas. They define models as an abstract, simplified representation of a phenomenon that makes central features explicit and visible which can be used to generate explanation and predictions.
Model-Based Reasoning

*Model-based reasoning* is a pedagogical approach to K-12 science that builds upon these aforementioned definitions of models. Model-based reasoning is the development of coherent and comprehensive explanation through the creating, testing, and revising of models (Kuhn, 1991). Through this iterative process, students evaluate and refine models.

Similarly, Lehrer & Schauble (2010) define model-based reasoning as the development, testing, and revision of models, emphasizing that modeling does not stop with the first representation students come up with: model-based reasoning centers on the evaluation and revision of a model based on student learning experience. Schwarz et al., (2009) also believe that model-based reasoning involves the construction and use of models as a tool for learning. They too emphasize the evaluation and revision of models as students learn new content. Further, Schwarz et al. (2009) have operationalized model-based reasoning into four key classroom practice elements: 1) students develop an initial model; 2) students use the model to explain, illustrate, and/or predict; 3) students compare and evaluate the accuracy of the model; and, 4) students revise models to increase its explanatory and predictive power. Similarly, Windschitl, et al., (2008) argue that model-based reasoning supports student development of evidence-based explanations. These authors see these representations as powerful stimuli for student conversation which can be iteratively tested and refined with the integration of other investigations, readings, and discussions. Successful instructional frameworks for modeling include: *engaging* with a question or problem in order to develop a initial model about causal relationship in the phenomenon; *developing* models of the phenomena that can account for observations; and, *revising* models to apply to new situations (Lehrer & Schauble, 2006; Passmore et al., 2009; Schwarz & White, 2005).
The Framework defines models as “a system (or parts of a system) under study, to aid in the development of questions and explanations, to generate data that can be used to make predictions, and to communicate ideas to others (NRC, 2012). The Framework indicates that students should be expected to evaluate and refine models through an iterative process.

Models Increase Content Development

Student experiences centered around scientific models show an increase in student achievement (Chan, Yang, Maliska, & Grluenbaum, 2012; Miller, McNeal, & Herbert, 2010; Rotbain, Marbach-Ad, & Stavy, 2006; Schwarz & White, 2005; Williams, 2011; Wu, Krajcik, & Soloway, 2001). Studies show a positive correlation between scientific modeling and student achievement. With hands-on physical modeling (Rotbain et al., 2006; Williams, 2011), as well as computer-based modeling (Schwarz & White, 2005; Wu et al., 2001), studies indicate quantifiable student gains.

While the construction of models is common in science classrooms (Campbell & Neilson, 2012; Neilson, Campbell, & Allred, 2010; Passmore & Stewart, 2002; Windschitl & Thompson, 2006), the experience of designing, constructing, evaluating, and revising scientific models makes for robust and engaging scientific experiences (Kenyon et al., 2008). This type of experience supports student learning by helping students to visualize the content (Chan et al., 2012; Rotbain et al., 2006) by making abstract concepts concrete (Schwarz et al., 2009; Xiufeng Liu, 2006) and giving students a point of reference as complex ideas evolve (Bogiages & Lotter, 2011; Campbell et al., 2012; Campbell & Neilson, 2012).

In a high school physics class learning about electricity, Williams et al. (2008) studied the impact of model-based inquiry on achievement. The eight-week model-based electricity unit employed diagrams, analogies, and investigations in order to engage students in incremental
model building of electrical circuits. The students who experienced the model-based electricity unit outperformed those who engaged in the more traditional approach to the material (Williams et al, 2008). Specifically, statistical analysis using a repeated measures analysis of variance (ANOVA), with an alpha of 0.05, determined that the students who received model-based instruction experienced significantly greater circuit problem-solving test score gains than did those who received the more traditional electric circuit instruction. While the control group scored a 38% on the post-test, the experimental group scored a 58% (Williams et al., 2008).

Studies also show increased student outcomes when teachers use computer-based modeling (Chan et al., 2012; Miller et al., 2010; Schwarz & White, 2005; Wu et al., 2001). Likewise, quantitative studies show the positive impact computer-based modeling has on student achievement: Schwartz and White (2005) studied a physics class that integrated scientific models to support content development. The physics curriculum was implemented in four 7th grade urban classrooms for approximately 45 minutes a day for ten weeks. Using computer technology, students created models representing their ideas about the principals of force and motion. Students tested their computer-based simulations and revised their models per computer feedback. An analysis of 87 students’ work indicates that they showed marked improvement in their knowledge of physics with a mean of 49% correct on the pre-test and 60% correct on the post-test (an increase of 11%).

**Model-Based Reasoning and Student Discourse**

In addition to an increase in content knowledge, the nature and types of conversations students engaged in when working with models improved and increased (Campbell et al., 2012; Windschitl et al., 2008). Windschitl et al., (2008) and Campbell et al., (2012) studied conversation patterns among students engaged in model-based science instruction. In both
studies students were engaged in deep, content-rich dialogue about science with peers, resembling the process engaged in by scientists.

Both studies analyzed science discourse among students and organized conversations into distinct categories. Windschitl et al., (2008) studied a middle school teacher’s model-based earth science lesson with students using tennis balls and an overhead projector to represent the moon and the sun, creating a model explaining the phases of the moon. At first the students struggled to create an initial model, but then the teacher, Mr. Gilbert, challenged each group with a series of questions to guide student thinking. Mr. Gilbert felt that his line of questioning led to a deeper understanding of content. By interacting with the teacher, students learned key facts about the phases of the moon and came up with ideas that led to enhanced second – and sometimes third – iterations of their model. Throughout the process, Windschitl and his colleagues watched and annotated the small group discussions, categorizing the discourse into four distinct categories of student discourse: 1) organizing what they knew and what they wanted to know; 2) generating hypotheses; 3) looking for evidence; and, 4) constructing arguments about why their models made sense. Each of these conversations directly linked to the student-created and -revised models, and resembled the work of true science. The dialogue noted by researchers led to the students’ deeper understanding of the content (Windschitl et al., 2008).

Similar discourse patterns were noticed by Campbell et al. (2012) who studied a high school physics class to examine the discourse pattern among students engaged in a model-based science inquiry. Similar levels of science discourse among students were noted as they negotiated and revised their understanding of physics by engaging in conversations with peers around scientific models. This study identified four types of discourse students engaged in with and around their models: 1) exploring discourse as they developed and revised models with
group members; 2) *retrieving discourse* to help grasp scientific concepts to enhance their model to be scientifically appropriate; 3) *negotiating discourse* as they tried to reach consensus about iterations of their model; and, 4) *elaborating discourse* in which student current knowledge is expanded with new content that is presented. In both studies, researchers noted qualitative data that indicated high levels of student engagement and participation – students were on-task, engaged, and collaborating as scientists (Campbell, 2012; Windschitl et al., 2008).

In addition to qualitative studies on student discourse, Kawasaki (2004) and Williams (2011) quantified the increased level of discourse in their studies of model-based science classrooms. Kawasaki examined the discourse patterns of students engaged in a ten-week unit on sinking and floating and used a discourse analytic tool to measure the social interaction among students in the classroom. To examine the difference in student participation, data from transcripts of eleven class sessions were recorded and analyzed. As a whole, the class took a percentage of speaking turns greater than what is typically seen in classrooms when engaging in model-based science instruction. In a class with a 55% student discourse rate, models increased the rate to 70.4% in one class and 92.6% in another (Kawasaki, 2004).

Similarly, Williams (2011), in studying a 9th and 11th grade physics classes learning about electricity, found similar data on student participation as a result of scientific modeling. Teacher-student discourse patterns were collected using computer-based software. In comparing the student participation in a model-centered class with a traditional science class, Williams (2011) found that 53% of the ideas presented in a model-based class were by students, while only 31% were presented by students in traditional classes. In both studies, quantitative data indicated positive correlations between student discourse and time spent on scientific models (Kawasaki, 2004; Williams, 2011).
Through these studies, the benefits of scientific modeling are clear: when students engage in scientific modeling, the level of student discourse and the quality of dialogue among students increases. By working with models, students come closer to replicating the conversations scientists engage in (Passmore & Svoboda, 2012).

**Increasing Academically productive Talk**

While student-centered discourse has benefits to student learning, research shows the benefit of well-structured opportunities for student talk on learning outcomes (Herrenkohl & Guerra, 1998; Michaels et al., 2008; Palinscar & Brown, 1984). Careful orchestration of talk opportunities has been shown to improve student outcomes (Alozie et al., 2009; Baker et al., 2009; Michaels et al., 2008; Smart & Marshall, 2013).

**Accountable Talk**

Over 20 years of classroom observations of student talk has identified what it takes to lay the foundation for a culture of student-centered reasoning. This research around academically productive talk has been coined *Accountable Talk* (Michaels et al., 2008).

Accountable Talk upholds a Vygotskian theoretical framework with the belief of “social formation of mind” (Michaels et al., 2008). Seminal work of Dewey (1966) and Mead et al., (1967) inform the Accountable Talk approach to developing a culture of discourse in the classroom, which relies on teachers to utilize questions calling for elaborated response by students. Moreover, Accountable Talk requires teachers to press students into developing their explanations, challenging their thoughts, and questioning others. It is a way of moving the conversation from the triadic dialogue (authoritative discourse) we see today toward a more dialogic approach wherein students are engaged in discussion.
Findings indicate that classroom subject matter guided by Accountable Talk leads to increases in student outcomes (Michaels et al., 2008). For example, in a U.K. program called Cognitive Acceleration through Science Education, students had opportunities to articulate their thoughts about science content through “thinking science” activities (Anderson et al., 2011). The curriculum opened many opportunities for students to talk about their explanations of a phenomenon, thereby deepening content knowledge. Three years after the course, student achievement in a British national exam showed significant effect size in these students’ math (.72) and English (.69) scores (Anderson et al., 2011).

Similarly, researchers from Boston University began a four-year intervention, Project Challenge, in a low-performing school district (Michaels et al., 2008). The intervention called for daily one-hour structured student talk about challenging math problems. Teachers utilized a variety of academically productive talk moves to press students into explicating their thinking and building on others’ thinking. After two years, these same students scored the highest probability of “giftedness” on a test for math abilities: 4% rose to 41%. In addition, 82% of student scored ”advanced and proficient” on the Massachusetts state test (Anderson et al., 2011).

Implications for Teacher Preparation

While the Common Core and Next Generation standards are calling for students to engage in more discourse-oriented activities (NGA-BP Initiative, 2012; NRC, 2012), research is showing the absence of talk in today’s science classrooms (Alozie et al., 2009; Cazden, 2001; Nassaji & Wells, 2000; Scott, Mortimer, & Aguiar, 2006). This dichotomy has implications for teacher preparation.

With the adoption of the new national standards, teachers are being asked to make an “unprecedented shift away from disparate content guidelines” (Porter et al., 2011, p. 103). The
Common Core and Next Generation standards require teachers to provide opportunities for critical thinking, problem-solving, and student-centered discourse. For example, students will have to move from engaging in prescribed lab experiments to creating a lab protocol of their own (NRC, 2012). Some argue that this move is an opportunity for U.S. schools to go beyond test-based, standards-based instruction (Conley, 2011). Specifically, Conley (2011) foresees classrooms moving away from traditional “worksheets, drill-and-memorize activities, and elaborate test-coaching programs, and towards an engaging, challenging curriculum that supports content acquisition through a range of instructional modes and techniques, including many that develop student cognitive strategies” (p. 1).

Rothman et al., (2012), however, believes that teachers who have been didactic in nature are not ready for this shift. Thus, teacher professional development and teacher preparation will need to realign their programs in order to prepare teachers for this change. Education reformers and researchers indicate that the success of the instructional shifts called for by Common Core and Next Generation standards lies in the ability to better prepare teachers; thus, the outcome of education reform depends on teacher training and preparation (Cuban, 1990; Garet et al., 2001). In a large-scale empirical comparison of the effects of different characteristics of professional development on teachers’ learning results, Garet et al. (2001) found that reform hinges on the qualification and effectiveness of teachers. Therefore, the successful integration of student talk in classrooms – which is the focus of this study – is dependent on how teacher education programs align and prepare for the demands of teaching these new standards.

Moreover, empirical evidence suggests that the quality of induction programs matter (Britton, Paine, Pimm, & Raizen, 2003; Johnson, 2004). Researchers found that the pre-service years determine a teachers’ trajectory of effectiveness (Adelman, 1991; McDonald, 1980).
McDonald (1980) states that "the development of a teacher is shaped or determined by what happens to the teacher during the transition period” (p. 25).

**Pre-Service Teachers and Modeling**

Because recent scholarship and national standards reflect the importance of student discourse in student learning, teacher education programs must also find ways to train teachers to be aligned to these new demands. Based on findings that indicate that modeling promotes discourse, this study is proposing the integrate modeling into teacher preparation programs.

A number of teacher preparation programs have already implemented and studied the model-based reasoning approach to teacher preparation. For example, Schwarz (2009) studied pre-service teachers' experience with model-based reasoning in a pre-service Methods course. Teacher learning outcomes based on teacher interviews and documents showed that pre-service teachers benefited from this coherent approach to lesson planning. Similarly, Schwarz and Gwekwerere (2007) studied pre-service elementary and middle school teachers as they incorporated model-centered scientific inquiry into their science teaching practices. Analyses of pre-service teachers' pre–post tests, classroom artifacts, peer interviews, and lesson plans throughout the semester indicated that the majority of pre-service teachers learned and used the new framework in their lesson plans and teaching. Most importantly, the framework and accompanying instruction enabled two-thirds of the class to move teaching orientations away from discovery and didactic approaches toward reform-based approaches such as conceptual change, inquiry, and guided inquiry. Results from this study (Gwekwerere, 2007) show that using instructional coherent and comprehensive frameworks can enable pre-service teachers to socially construct, synthesize, and apply their knowledge for enacting reform-oriented science teaching approaches such as model-centered scientific inquiry. Ogan-Bekiroglu (2007) also
studied the impact of a model-focused pre-service course and found that the effects of model-based teaching shifted from flawed mental models to correct mental models of the Moon and lunar phenomena.

**Science Methods Course – Fall 2013**

*You will learn about and develop models, using models as one of the important practices to help your students support their understanding and explanations of natural phenomena. Part of developing an understanding of models will come from focusing on building a classroom culture of reasoning and arguing from evidence where students go public with their ideas and build on the ideas of their classmates.*

– Course Syllabus

During the fall of 2013, a Secondary Science Teachers Education Program revised its existing Methods course to reflect the current research on model-based instruction. In addition, the course layered on the Accountable Talk framework to promote productive talk as students worked with models. Through the ten-week Secondary Science Methods course, pre-service teachers experienced modeling and talk as adult learners, examined videos of classroom talk, and reflected on implications for their own practice.

**Modeling to Learn**

As part of the ten-week pre-service Methods course, pre-service students engaged in lessons to deepen their understanding of the structure and properties of matter, a core physical science concept. The learning experience included the development and revision of models that represent their most current ideas about matter. These models evolved over time.

Specifically, pre-service teachers observed certain phenomena and developed models to explain them. Students were asked to explain the phenomena by drawing a model of what might be happening. For example, upon pouring warm water into a plastic water bottle and capping it, the bottle began to collapse on itself. Student teachers drew an initial model. Thereafter, students
experienced multiple hands-on activities in which they learned new content. This new content helped to further explain the imploding water bottle. As a result, students were able to revise their model throughout the unit.

**Accountable Talk**

A great deal of discussion took place through the modeling experience. Pre-service teachers worked in pairs, small groups, and as whole group to engage in academically productive discourse. The instructor utilized the Accountable Talk Moves to facilitate the conversation.

**Examining Data Through Accountable Talk**

Academically productive talk is critical for learning in science (Duschl et al., 2007). Michaels and O’Connor (2012) identify four goals to promoting discussions that lead to greater learning (See Table 1). This study will align all findings to the Accountable Talk Goals.

**Table 1: Accountable Talk Goals and Talk Moves**

<table>
<thead>
<tr>
<th>Accountable Talk Goal #</th>
<th>Teachers’ Role</th>
<th>Students’ Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Help individual students share, expand, and clarify their own thought.</td>
<td>Share thoughts and responses out loud in a way that is understandable to others.</td>
</tr>
<tr>
<td>2</td>
<td>Help students listen carefully to one another.</td>
<td>Students listen to others and try to understand them in order to contribute to the discussion.</td>
</tr>
<tr>
<td>3</td>
<td>Help students deepen their reasoning.</td>
<td>Students use solid and sustained scientific reasoning; push to understand and deepen reasoning.</td>
</tr>
<tr>
<td>4</td>
<td>Help students engage with others’ reasoning.</td>
<td>Students take up the ideas and reasoning of other students and respond to them.</td>
</tr>
</tbody>
</table>

In addition to experiencing the Accountable Talk Moves, pre-service teachers read “The Talk Primer” (Michaels & O’Connor, 2012) to understand the research on the importance and benefits of student talk.
Teacher Reflection Throughout Secondary Methods Course

The pre-service teachers reflected on their learning experience throughout the ten-week Methods course. The written reflections indicate that teachers found models to be an effective approach to teaching content, particularly abstract science content:

[A] model is useful because it helps students make the transition between something familiar and something new.

[It’s] easier to explain with something real than something abstract, like air molecules that we can't actually see.

They are helpful to understand new concepts.

In addition, teachers experienced and reflected on the benefits of student discourse. They all understood the importance and importance of engaging students in Accountable Talk.

It's important that students learn content, but it's even more important for them to reason out their ideas and thoughts using evidence. By discussing it with other students, they are able to defend their ideas and be open to others as well.

It creates an environment of little scientists [who] support their reasoning with evidence and also allows rich discussions on why other views are valid or invalid. In our own classrooms, talk should be used as a powerful tool for learning and facilitating scientific discussions.

[T]he importance of discussion not only between teacher and student, but also between the students themselves. Discussion/talk should be encouraged within the classroom setting, allowing ideas to bounce back and forth between students, however, certain guidelines must be set forth to make discussion productive.

Classroom discussion is a valuable tool in teaching science. It is absolutely necessary that our students learn science content but they must also be able to communicate their knowledge and this skill must be learned during classroom discussion.

In fact, one teacher hit the nail on the head by indicating the importance of student in the new standards:
Productive talk and science talk is going to be crucial for the students in the Next Generation Science Standards. Productive talk allows the students to reflect and explain their thinking while increasing the social skills of themselves and others.

Modeling to Promote Academically Productive Talk—Proposed Study

Throughout the Secondary Science Methods Course, pre-service teachers reflected on and experienced Accountable Talk in the context of modeling activities. Their reflections indicated that they understood the benefits of modeling and talk activities. This study followed pre-service teachers into their first-year as a classroom teacher and sought to examine teachers’ uptake of modeling activities to promote academically productive talk.
CHAPTER 3: METHODOLOGY

The Common Core and Next Generation Science Standards emphasize student-centered discourse, yet research indicates that discourse opportunities are absent from today’s classrooms (Alozie, Moje, & Krajcik, 2009; Lemke, 1990; Nassaji & Wells, 2000; Newton, Driver, & Osborne, 1999). In order to meet the discourse demands of these new standards, science teachers need to learn how to integrate strategies that open up students’ opportunities to engage in academically productive talk with one another.

Because models and modeling activities have been shown to increase student-centered discourse in science classrooms (Campbell et al., 2012; Kawasaki, Herrenkohl, & Yeary, 2004; Windschitl et al., 2008), one public university’s teacher preparation program redesigned its Fall Secondary Science Methods Course in order to focus on modeling as an approach toward promoting academically productive, student-centered talk. I chose to examine this program to learn whether and how this new approach better prepared teachers for the discourse demands of the Next Generation Science Standards. This study examined how new teachers transferred strategies from their Methods course into their first year of teaching. Specifically, this study examined how new teachers opened up opportunities for student talk through modeling activities. I sought to answer the following research questions:

1) What do first-year teachers say about the goal of student talk?

2) How do first-year teachers believe modeling supports student talk?

3) How are these perceptions about modeling to support student talk realized in the classroom?
Project Overview

In response to the changing landscape of science education, a teacher education program at a public university redesigned its Fall Secondary Science Methods coursework. In particular, the Methods courses emphasized the centrality of talk in the Next Generation Science Standards. Throughout the first year of teacher preparation, teachers who participated in this study learned about the goals of Accountable Talk and the nine talk moves that support each of these goals as a means for students to engage in talk. In addition, monthly visits by their faculty advisor utilized an observation rubric that quantified evidence of student discourse (Appendix C).

Because modeling activities have been found to increase student talk (Campbell et al., 2012; Windschitl & Thompson, 2006), the Methods course, taught in the fall of 2013, focused on developing teachers’ understanding of models and modeling as an approach to open up opportunities for student talk. Pre-service teachers experienced first-hand how to use models as a way to explain interesting phenomena; in this case, teachers observed a video clip of an imploding steam tank and were asked to explain this phenomena by drawing a model. Through a sequence of hands-on investigations and text-based analysis, teachers’ explanations of the phenomena at-hand grew clearer; this led to the revision of their models after group interactions and discussions. Once participants became more familiar with the process and benefits of modeling, they were asked to design a unit that engaged students in the development and revision of models as a way to support explanation development and open up productive student discourse.

This study sought to examine the first-year teacher’s perspective on student talk and how these perspectives are transferred into practice. Specifically, during the fall quarter of 2014 (September to December), this study examined how teachers used modeling to promote
Accountable Talk and pedagogical concepts introduced during a Methods course a year earlier (Fall Quarter of 2013). The aim in collecting teachers’ first units was to understand how new teachers make sense of the pedagogy presented in their course work – such as modeling and Accountable Talk – as they try to enact them for the first time in their classrooms. This shed light on the challenges teachers face in adopting ambitious teaching practices that, in turn, can inform teacher preparation and professional development.

**Research Design**

This study sought to understand new teachers’ perspectives on student talk and how these perspectives are transferred into practice. It is a window into how new teachers might be making sense of their pre-service learning experiences. Because this study “has as its goal understanding how people make sense of their experiences” (Merriam, 2009, p. 37), it utilized a basic qualitative research design. Data are collected through interviews and classroom observations in order to inductively address the research questions.

**Methods**

Because this study sought to examine details about teacher practice, the research took place in the classroom. Classroom observations provided the detailed description and explanation (Maxwell, 2004; Patton, 1980; Yin, 1994) about how teachers used models to promote and engage students in productive talk. In addition, data from interviews with teachers enabled inferences to be drawn about their perceptions – in this case, the goal of student talk (Denzin & Lincoln, 1994; Marshall & Rossman, 1999; Maxwell, 2004). As a result, the thick and rich description provided through interviews and classroom observations provided insight into how teachers perceive and used models as a way to promote talk to promote productive classroom conversations (Creswell 1994; Gertz 1973).
Site Selection

In order to meet the demands of the Next Generation Science Standards, the Secondary Science Faculty Advisor redesigned the Science Methods Course to reflect the new discourse demands. The course was revised in ways that highlighted modeling as a way to open up opportunities for productive and Accountable Talk. Because this study was connected to the Methods course that was revised and taught in the fall quarter of 2013, the data for this study was collected from the same participants who engaged in the Methods course a year later (fall of 2014).

This particular public state university teacher education program offered a two-year secondary science credential and masters degree. During the first year, pre-service teachers are enrolled in education courses and worked in classrooms as student teachers. During the second year of the program, teachers continued to attend weekly seminars in the evening while assuming full-time teaching positions. This study took place during the second year, which is considered the first year of teaching for participants.

Participants

Ten (10) out of the 12 teachers who completed the redesigned secondary science Methods course participated in this study. Each of these teachers experienced the pre-service course focused on modeling to promote academically productive talk in the fall of 2013. All teachers found a teaching placement in a secondary science school classroom and were invited into the study.

Ten teachers opted into the study—a pseudonym was used for each participant. As mentioned, each teacher participated in the Secondary Science Methods course in 2013 and consented to participate in this study.
Data Collection

In addition to assuming a full-time teaching position, all participants enrolled in ED 498A, an evening seminar course that met once a week during the fall quarter of 2014. During this quarter, three key steps made up the data collection effort for this study. First, teachers had to submit a modeling unit plan. Second, I observed each teacher multiple times throughout the teaching of the modeling unit. Finally, I conducted and interview with each teacher. Table 2 summarizes the timeline for data collection.

Table 2: Timeline for Data Collection

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Plan Collection</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Classroom Observations</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Teacher Interviews</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Unit Plan Development

This study was dependent on each teacher’s ability to design and implement a modeling unit. Hence, I co-facilitated three seminar sessions wherein I: 1) revisited the content objectives of their pre-service methods courses, 2) reviewed the model-based reasoning framework, and 3) supported the development of teachers’ first modeling unit.

On September 3, the first session of the course, participating teachers had an opportunity to reflect and connect the material they learned during their pre-service year to the goals of ED 498A. The instructor walked through the course syllabus (Appendix A). One requirement, making up 20% of the course, was for teachers to develop and teach a Model-Based Unit Plan. Towards the end of the first session, I was able to review my research interest and walk through the consent form. In order to remind teachers of the modeling framework they experienced...
during their pre-service year, I reviewed the modeling framework introduced on September 10, the second session of the course (Figure 2).

**Figure 2: Framework for Planning Modeling Unit**

![Diagram of the modeling framework](image)

Thereafter, teachers had an opportunity to move into content-alike groups and begin brainstorming ideas for their modeling units. Subsequently, on September 27th, teachers were given more time to collaboratively develop their modeling units. Thereafter, teachers submitted their unit plans scheduled to be taught between October and December 2014. The assignment was due on October 15, 2014.


Classroom Observation

Once teacher participants submitted unit plans, I scheduled a pre-observation meeting with each individual. During this meeting, the participant and I identified lessons within the unit that would encourage students to work with models. Together the teachers and I selected three lessons through which to observe students: 1) developing an initial model, 2) evaluating this model, and 3) revising their model. Teachers identified the dates that the selected lessons might be taught. I created a calendar of all observations over the three-month period. Table 3 presents a summary of the classroom observations conducted for this study:

Table 3: Classroom Observation Date and Time

<table>
<thead>
<tr>
<th></th>
<th>Day ONE</th>
<th>Day TWO</th>
<th>Day THREE</th>
<th>Day FOUR</th>
<th>TOTAL Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andy</td>
<td>10/6/14</td>
<td>0:45</td>
<td>10/9/14</td>
<td>1:15</td>
<td>10/13/14</td>
</tr>
<tr>
<td>Angel</td>
<td>11/4/14</td>
<td>1:45</td>
<td>11/7/14</td>
<td>1:00</td>
<td>11/18/14</td>
</tr>
<tr>
<td>Biron</td>
<td>10/14/14</td>
<td>1:10</td>
<td>10/20/14</td>
<td>0:50</td>
<td>10/28/14</td>
</tr>
<tr>
<td>Christine</td>
<td>12/1/14</td>
<td>0:50</td>
<td>12/9/14</td>
<td>1:25</td>
<td>1:50</td>
</tr>
<tr>
<td>John</td>
<td>10/16/15</td>
<td>1:25</td>
<td>10/21/15</td>
<td>1:50</td>
<td></td>
</tr>
<tr>
<td>Kevin</td>
<td>10/13/14</td>
<td>0:50</td>
<td>10/16/14</td>
<td>0:55</td>
<td></td>
</tr>
<tr>
<td>Mike</td>
<td>11/3/14</td>
<td>1:45</td>
<td>11/6/14</td>
<td>1:10</td>
<td></td>
</tr>
<tr>
<td>Santana</td>
<td>12/1/14</td>
<td>0:55</td>
<td>12/3/14</td>
<td>0:45</td>
<td>12/5/14</td>
</tr>
<tr>
<td>Sarah</td>
<td>10/30/14</td>
<td>0:55</td>
<td>10/31/14</td>
<td>0:55</td>
<td>11/4/14</td>
</tr>
<tr>
<td>Sunny</td>
<td>10/17/15</td>
<td>1:20</td>
<td>10/22/14</td>
<td>0:40</td>
<td>10/29/14</td>
</tr>
</tbody>
</table>

Because this study sought to understand how first-year teachers open up opportunities for students to engage in Accountable Talk, data were collected during whole-class instruction. For the purpose of this study, “whole-class instruction” is defined as instruction facilitated by teachers (i.e., lecture or didactic discussion). Table 4 summarizes the percent of whole-class instruction over the total instructional time I observed. The findings from this study reflect this portion of classroom observations.
Table 4: Percentage of Whole-Class Discussion

<table>
<thead>
<tr>
<th></th>
<th>% Whole-Class Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andy</td>
<td>31%</td>
</tr>
<tr>
<td>Angel</td>
<td>33%</td>
</tr>
<tr>
<td>Biron</td>
<td>34%</td>
</tr>
<tr>
<td>Christine</td>
<td>33%</td>
</tr>
<tr>
<td>John</td>
<td>27%</td>
</tr>
<tr>
<td>Kevin</td>
<td>34%</td>
</tr>
<tr>
<td>Mike</td>
<td>39%</td>
</tr>
<tr>
<td>Santana</td>
<td>30%</td>
</tr>
<tr>
<td>Sarah</td>
<td>26%</td>
</tr>
<tr>
<td>Sunny</td>
<td>32%</td>
</tr>
</tbody>
</table>

It is important to note that I did not reveal what I was observing during classroom observations. While teachers knew I was observing their modeling unit, they did not know that I was examining discourse in the classroom, particularly their use of talk moves. I videotaped each classroom observation and took observation notes throughout. Thereafter, I transcribed what teachers said during all whole-class instructions across all observations.

Teacher Interviews

In order to gain insight into new teachers’ perceptions of the goal of student talk, I interviewed each teacher participant. The interviews took place after each individual teacher finished teaching their unit. This was an intentional part of the research design as I did not want teachers to know that I was collecting data on Accountable Talk. We met either in teacher classrooms or online, whichever was more convenient for the teacher and his or her schedule. Each interview was audio-recorded and transcribed.

An interview protocol (Appendix C), as well as a summary of talk moves utilized by each teacher during classroom observation, was used to guide the interview process. The semi-structured interview consisted of questions designed to understand each teacher’s perception of student talk. The interview started with a series of reflective questions about the observed modeling unit. Thereafter, teachers were asked about their perceived goals for student talk, as well as the benefits of modeling to support student talk: it was at this point of the interview that I revealed my interest in their integration of the Accountable Talk pedagogy. This was a strategic
research design decision as I did not want to influence any teacher responses to questions related to the goal of talk. I then shared the individual talk moves data with each teacher. Teachers had an opportunity to examine and reflect on their use of talk moves during their unit. The interview concluded with teachers’ reflection.

Data Analysis

This study required data analysis of teacher interviews and classroom observations. In both cases “the analysis of the data involved identifying recurring patterns that characterize the data” (Merriam, 2009, p. 24). For this study, classroom observation data was analyzed prior to the interview for each teacher participant. This provided the participant an opportunity to reflect on the talk moves data observed during the classroom observation. Interviews were analyzed collectively after all teachers were interviewed.

Classroom Observation

In order to analyze how teachers actually used models to support talk, classroom video transcripts were analyzed. For each classroom discussion, I transcribed teacher talk, and highlighted the transcription with all talk moves each teacher uttered. I followed up by creating an Excel spreadsheet to tally the use of talk moves. Once the talk moves were organized into a spreadsheet, I created a visualization representing the frequency of talk moves used by each teacher. Table 5 and Figure 3 represent a sample table and chart I developed for each teacher. The data provided insight into the patterns and trends of how each teachers used the talk moves to engage students in talk during their modeling unit.
Table 5: Sample of Frequency of Talk Moves for Single Teacher

<table>
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<tr>
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<tbody>
<tr>
<td>Initial</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Evaluation</td>
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<td>3</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Revision</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
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<tr>
<td>Total</td>
<td>9</td>
<td>7</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>12</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 3: Sample of Visual Representation of Data for Single Teacher

Interviews

In order to understand how first-year teachers perceive student talk, I coded interview responses, then categorized and mapped them to the four goals of Accountable Talk (Michaels & O’Connor, 2012). In order to increase the reliability of the coding, an education doctoral student specializing in qualitative research methods also coded and categorized the interview responses across the four goals of Accountable Talk. After an in-depth, in-person conversation about the project and the Accountable Talk goals, this second rater was provided with a code key containing definitions of each goal, as well as at least one example of how each goal may be
identified in the context of an interview. Across 23 quotes, there was an 89% inter-rater agreement. Similarly, this method was also used to examine first-year teachers’ perceptions of the goals of talk in a modeling unit. In order to increase the reliability of the coding, the same rater also coded and categorized the interview responses across the four goals of Accountable Talk. Across 32 quotes, there was an 87% inter-rater agreement.

**Validity**

The primary goal of my research was to understand teachers’ perceptions of the goal of student talk and to see how these perceptions were translated into the classroom. A number of measures were taken to ensure the validity of this study. First, because of my relationship with the participants, I needed to be sure to avoid issues of social desirability. While teachers knew I was observing their modeling unit, I did not tell them what I was observing and what I was looking for – they simply knew I was interested in their modeling unit. So, while they might have taught the unit to appease me, the fact that I did not disclose what I was looking for specifically protected me from issues of social desirability. The interview also took place after the classroom observation so that teachers did not know about my interest in student talk.

In order to ensure reliability of how I coded and categorized my interview data, I hired an expert in qualitative data analysis to re-code my interview data. This check increased the inter-rater reliability, which supports the validity of my findings.

**Summary**

For this study, I observed two-four lessons of a modeling unit to understand how first-year teachers promote Accountable Talk; I also interviewed teachers to understand their perception of student talk. Through these structured interviews and classroom observations and careful analysis of the data, I was able to reach my findings.
CHAPTER 4: FINDINGS

The Next Generation Science standards emphasize the importance of student-centered learning (NRC, 2012). In particular, they highlight the necessity of student-centered talk in learning science. This study identified first-year teachers’ perspectives on the goal of student talk, as well as their perspectives on how models and modeling activities support student talk. Further, this study examined how teachers transfer their ideas about student talk to the classroom. This chapter presents my analysis of interview and observational data to answer the following research questions;

1) What do first-year teachers say are the goals of student talk?

2) How do first-year teachers perceive modeling supports student talk?

3) How are these perceptions realized in the classroom?

I begin by presenting first-year teachers’ perspectives on the goals of student talk, then I present findings on how these first-year teachers think modeling supports it. Finally, I use classroom observation to identify how teachers’ perspectives on modeling and student talk are realized in their classrooms. As a reminder, this study utilized the Accountable Talk Goals framework (Michaels & O’Connor, 2012) set forth in Table 6.

Table 6: Accountable Talk Goals and the Talk Moves that Support Each Goal

<table>
<thead>
<tr>
<th>Goal 1: Individual students share, expand, and clarify their own thinking</th>
<th>Talk Move</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal 2: Students listen carefully to one another</td>
<td>4. Who Can Rephrase or Repeat?</td>
</tr>
<tr>
<td>Goal 3: Students deepen their reasoning</td>
<td>5. Asking for Evidence or Reasoning</td>
</tr>
<tr>
<td></td>
<td>6. Challenge or Counterexample</td>
</tr>
<tr>
<td>Goal 4: Students think with others</td>
<td>7. Agree/Disagree and Why?</td>
</tr>
<tr>
<td></td>
<td>8. Add On</td>
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<tr>
<td></td>
<td>9. Explaining What Someone Else Means</td>
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First-Year Teachers’ Perspective on the Goals of Student Talk

Through an interview each teacher was asked to discuss what goals might be served by engaging students in sustained student talk with each other. I mapped teachers’ expressed ideas into the four broad goals behind Accountable Talk (Michaels & O’Connor, 2012), as shown in Table 9.

Three patterns stand out in the Table 7. First, as described in more detail next, all 10 teachers expressed some version of the goal of having students share their thinking, which aligns to the Goal #1 of Accountable Talk. Second, 2 teachers explicitly expressed a goal of having students listen to each other (Accountable Talk Goal #2). Third, only 1 teacher mentioned the goal of students explaining the reasoning behind their ideas, while 6 teachers said student talk served for students to engage with each others’ ideas, aligning with Goal #3 and Goal #4 respectively.
Table 7: Teachers' Expressions of Accountable Talk Goals Supported Via Talk

<table>
<thead>
<tr>
<th></th>
<th>Goal #1</th>
<th>Goal #2</th>
<th>Goal #3</th>
<th>Goal #4</th>
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<tbody>
<tr>
<td>Andy</td>
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<tr>
<td>Angel</td>
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<td></td>
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<tr>
<td>Biron</td>
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<tr>
<td>Cristine</td>
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<td>John</td>
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<td>Mike</td>
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<td>Santana</td>
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<td>Sarah</td>
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<td>Sunny</td>
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</tbody>
</table>

Talk As a Means for Students to Share Their Thinking

All 10 teachers stated that the goal of student talk was for students to share their thinking. According to these teachers, student talk makes student thinking visible, clarifies understanding of content, and is a valuable formative assessment tool, all concepts which are important to student learning and linked to Accountable Talk Goal #1.

Make thinking public. All 10 teachers expressed the idea that when students share their ideas, it makes those ideas publicly available for the entire class to consider. Biron said, “I think [student talk] is about sharing ideas with each other and making them public.” Santana and Angel also emphasized the importance of making one’s idea public; they each said the purpose of student talk is for students to “communicate their thinking out loud” and to “share and communicate ideas for their classmates to hear.” For these teachers, the value in making various ideas public was to then be able to explicitly consider their merits and move discussion forward.

Clarify understanding of concepts. Six (6) teachers (Kevin, Santana, Angel, John, Sarah, and Andy) said student talk helped students clarify their understanding of content.
Santana said student talk is “a way for students to solidify their understanding of a concept” and Kevin indicated that student talk is an important part of the learning process as it helps students “talk out their thinking to emphasize what they’re learning and to express the content.” As a result of having a clearer understanding of content, Sarah and Andy said that students should be able to “share their ideas if they understand the concept from beginning to the end” and “be able to discuss scientific concept with real terms, real vocabulary.” The focus in these examples is on the scientific accuracy of student talk, more than its being public.

**Talk as formative assessment.** Five (5) teachers (Cristine, Angel, Sarah, Mike, and John) described student talk as a tool for formative assessment. Student talk, as Cristine said, “makes you realize how much they already know, but also maybe some misconceptions that just needed to be a little tweaked.” Student talk as a tool for identifying misconceptions was the common idea in this theme. Mike said, “If they're not speaking to me then I have no idea what they do or don't know.” Teachers also noted that students’ reluctance to share their thinking was an indication of a lack of understanding of the topic at hand. Angel said, “When students don't understand the topic, I often find that students don't want to engage in science talk. When the students don't feel comfortable with the topic and they don't really understand much about the topic, they just don't engage at all.” According to these 5 participants, teachers are able to assess student understanding—or lack thereof—which is important in promoting productive talk.

**Talk Engages Students in Reasoning with Evidence and Each Other**

While all teachers expressed reasons for students to share their thinking, a subset of them indicated that the purpose of student talk was for students to engage in student-centered discussion and reasoning with evidence. Specifically, 5 teachers emphasized the importance of student-to-student interaction, and 1 teacher said that student talk was a way to deepen reasoning
with evidence.

**Student-to-student interaction.** Five (5) out of the 10 teachers (Andy, Biron, Kevin, Mike and Sunny) indicated that the goal of student talk is for students to enter into discussion among themselves. In their responses, these four teachers emphasized student-to-student interaction. For example, Biron said the “main goal of talk is class discussion.” He envisioned student talk as an opportunity for students to engage in student-centered dialogue. Similarly, Angel also said that the goal of content development is for students to be able to engage in discussion. She reflected, “If you feel comfortable with the material that you learned, then you should be able to talk to another person about it and speak with the appropriate academic language very freely.” Both Angel and Biron said that the goal of talk should be for students to engage in student-centered discourse, a vision stated in Accountable Talk Goal #4.

These 4 teachers (Biron, Andy, Sunny, Kevin) also said that student talk is a way to engage students in argumentation. Biron indicated that students should be “challenged by the people they are talking to.” For Biron, the value of students “challenging” each other is that it demands students to produce evidence to support their ideas. Andy extended this interest in evidence-based reasoning to include science concepts:

[Students] either questioning or arguing or taking a stand and being able to talk to each other… saying, "I think my argument is this because…," or, "I disagree with you because..." Student talk is students actually being able to discuss a scientific concept with real terms, real vocabulary, real evidence.

These teachers articulated the importance of student-to-student interaction and evidence-based reasoning in the service of helping students make sense of content, thereby aligning to Accountable Talk Goal #4.

**Reasoning.** Only 1 teacher, Sunny, mentioned that student talk should include students
having to explain their reasoning more deeply. She said, “Student talk is students working with evidence or having students engage in evidence-based reasoning.” Engaging with data and evidence, according to Sunny, helped students engage in conversations that exhibit deeper reasoning skills and higher level thinking, an important way to develop students’ content knowledge. This perception is aligned to Accountable Talk Goal #3.

**Summary of First-Year Teachers’ Goal of Student Talk**

Considering these teachers as a group, all of them expressed the primary value of student talk as a means for students to share their thinking which aligns to Accountable Talk Goal #1. Most of them saw this sharing as serving the purpose of getting ideas out into the open, especially misconceptions. Five teachers (Biron, Andy, Kevin, Mike and Sunny) suggested one reason for students to share their thinking was so they could really engage in the back and forth discussion aimed at evaluating and developing their ideas, i.e., engaging in Accountable Talk Goal #4. None (0) of the teachers explicitly mentioned a goal of having students listen to each other. These patterns may be partially a result of the generality of the interview question, which simply asked teachers to discuss the value of student talk. As seen in the next section, when asked how modeling supported student talk, as a group, these teachers expressed a richer set of goals.

**First-Year Teachers’ Perspective on Modeling to Support Student Talk**

Each teacher designed a series of lessons in which students collaborated to develop and revise models in order to explain phenomena. This section uses teachers’ interview responses to answer the second research question: *How do first-year teachers perceive modeling supports student talk?* As with Research Question #1, teachers’ reasons for using modeling were analyzed in relation to the Accountable Talk goals as a way of considering how these teachers
perceived modeling as supportive of student discourse. Interview responses indicated that the modeling process helped these first-year teachers organize student talk in ways that more explicitly addressed the goals for Accountable Talk, as summarized in Table 8.

**Table 8: Teachers' Expressions of Accountable Talk Goals Supported Via Modeling**

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<tr>
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<th>Goal #1</th>
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<td>Angel</td>
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<td>Biron</td>
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<td>Cristine</td>
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<td>Mike</td>
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<td>Santana</td>
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<td>Sarah</td>
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<tr>
<td>Sunny</td>
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In comparison to the broader question of the goals of student talk, when asked about modeling, these teachers were much more explicit about each goal, thereby increasing alignment to the Accountable Talk Goals. Table 8 indicates that more teachers expressed that modeling addresses multiple goals. In the following sections, I address how teachers talked about each of the four accountable talk goals in relation to student modeling.

**Modeling Opens Up Opportunities for Students to Share, Explain, and Clarify Ideas**

As they did in response to the general question about student talk, all 10 teachers said that models helped students share, explain, and clarify their thinking. When talking about modeling, teachers expressed a variety of ways such talk met this goal. They said that models increased student participation, served as an explanatory tool, and connected to prior knowledge. These varied responses align to and support students’ engagement with Accountable Talk Goal #1.
**Opportunity to share.** The modeling process, as taken up by teachers in this study, involved students developing and revising a model over time. All 10 teachers in this study articulated that this collaboration opened up opportunities for each student to share his/her thinking. Santana said models “Get students’ initial thinking of a particular question, problem, concept out,” which helped students share their ideas. Angel indicated that she had to be explicit about this process because it was a new approach to learning. She said the modeling process gave students a concrete reason to share. She said she had to clearly articulate, “Once you share your idea, you want to incorporate that idea into your model,” which led to more talk among students as they collaboratively revised their models.

All teachers in this study also had students present their group model to the class. Teachers said that this was an important part of the modeling process as it made student thinking public. The presentations opened up, again, an opportunity for students to share their thinking in order to contribute to class discussion.

**Models as an explanatory tool.** Six (6) teachers (Santana, Sunny, John, Sarah, Kevin and Biron) said that models help student explain their thinking. These teachers highlighted key parts of the modeling process that invited students to explain their thinking via models and modeling. Biron shared his experience with initial models: “having them make the initial model just gave an entry point to that explanatory reasoning based discussion.” Because it is based on prior knowledge, the initial model stage invited students to explain their preliminary thinking, which contributes to the discussion with and about models. Furthermore, the model revision process is mentioned as another way teachers use models as an explanation tool. Sarah said that “model revisions help explain their thinking,” adding that “the visual model helped students explain what they know from the model.”
**Individual models clarify thinking.** The “time to think” talk move is that which teachers used in order for students to reflect individually. While all teachers used this talk move with high frequency, 5 teachers (Santana, Angel, Sandy, Mike, and Sarah) shared that the time to develop an individual model was an important part of helping students clarify their thinking. Angel said, “I made sure that they each came up with a design first,” and Santana said, “Having them do something individually beforehand just gave them something to share.” These teachers articulated the importance of giving students time to think and process individually before entering into group discussion. This individual time gave students an opportunity to reflect on what they knew, collect their thoughts, and draw a model that reflects what they know prior to entering into small-group work. This quiet time was a way for students to clarify their thinking to support discussion.

**Modeling Helps Students Listen to One Another**

When asked about the purpose of student talk in general, not one (0) teacher mentioned the importance of listening. Seven (7) teachers, however, said student collaboration with and about their models helped students engage in active listening. They indicated that the collaborative modeling process presented a meaningful and concrete reason for students to listen to one another.

**Collaborating with models requires active listening.** Seven (7) teachers (Andy, Angel, Biron, Mike, Santana, Sarah and Sunny) mentioned that the collaborative, student-centered nature of the modeling process presented an authentic opportunity for students to actively listen to one another. The development of a group model required students to not only share, but also to carefully listen to the quality of the ideas presented by peers. Because most initial ideas are based on prior knowledge and experiences, teachers said the group model piqued students’
interest. Andy said, “They got to see other people's thoughts. Everyone brought in their own thoughts and background information which was slightly different and they actually got to either question it or learn something new.” Similarly, Santana highlighted the fact that developing a group model required students to listen and address questions posed by their peers. She said, “Together they can come up with one cohesive model that incorporates all of their ideas together, and I think that’s a good way to get them to discuss.” As students collaborated on developing and revising models, they not only had to talk, but had to carefully listen to one another’s ideas.

Further, all teachers opened up opportunities for students to present their group models. Angel said, “I can't help but go back to the presentations that they did. The part that stood out to me the most was when the students were asking questions, and they were answering their questions at the very last part.” The back and forth that Angel experienced between her students was evidence that they were engaged and listening to one another’s presentation. Mike and Sunny also expressed that students depend on each other to revise their model by listening to the ideas presented by peers. Mike said, “Modeling requires student to get stuff from their peers,” which requires active listening. And as students collaborated on developing and revising their models, Sunny said this process “push[ed] them to listen and help each other.”

**Modeling Provides Opportunities for Students to Revise Thinking**

All 10 teachers noted that the iterative cycle of modeling helped students engage in conversations that led to deeper reasoning. As students learned more content, they were able to identify additional data to add to and/or to modify their models. Because students were working on a group model, they had to agree on the changes proposed. As such, these conversations reflected students’ engagement in evidence-based reasoning. Teachers said that the revisions led to deeper reasoning and deeper questions, and also had implications for their practice in
designing instruction.

**Deepens reasoning.** Seven (7) teachers emphasized that the process of revising models opened up opportunities for students to engage in conversations about evidence. Students were able to revise their model because they acquired more data. Angel said, “I thought having them remodel was a perfect opportunity for them to apply new information that they learned… based on reasoning.” Similarly, Santana said “students use experiences, what they learned, what evidence they found to refine what they think. Basically, they adapted what they learned to what they knew before.”

Conversely, 2 teachers indicated that their students had a difficult time adding and modifying their models if they did not learn anything new. John said, “I can't believe they said this, but they stopped revising their model. They thought the first initial model was perfect. They were like, ‘We don't have to make changes; it's pretty good as it is.’” Mike said, “Nothing was changing about the model at that point because they weren't given time to do research,’’ and as a result, did not have additional evidence. Both these teachers indicated that students had nothing to change about their model and completely disengaged from the group work. Other teachers noted that when students were able to revise their model, they engaged in talk to revise their model, but that the lack of additional evidence resulted in low talk and engagement.

**Opportunity for questioning.** Three (3) teachers (Sunny, Mike, and Kevin) emphasized the important role of questioning to engage students in deep reasoning. Sunny said, “Well, I try to start off with questions that seem simple, and end up having some sort of deeper explanations.” She provided examples of the types of questions she might use:

“What’s going to happen with this?” is a fairly simple question, but if you have them see through the discrepant, they start trying to explain it, and you keep asking “Why? Why? Why?” or “By what?” or “Through what?”
Kevin conceptualized the importance of questioning in the same way:

I think of modeling as sort of a sandbox, in a computer program, there's a think called sandbox, which is basically, you can run programs. I think of a model as a sort of a program in your head, a sandbox, that you're just running a simulation on, like “Does this fit with my model?” “Would this break my model?” “Would this work?”

In order for students to engage in talk aligned for deeper reasoning, teachers indicated that students needed to be able to ask questions that frame deeper discussions about their models. These questions lead to deeper reasoning.

**Instructional design matters.** Five (5) teachers expressed the importance of designing learning experiences that support reasoning with one another. Specifically, teachers said that modeling units have to be carefully designed so that students can revise their models and engage in talk. Biron talked about integrating more sources of evidence to help students refine their thinking. He discussed the importance of having students refer to data, i.e., “pull pieces of that from their graph or something and use that to explain their thinking during the discussion.” He emphasized the importance of having students talk about new evidence and data that should be added to the model. Andy and Santana said they utilized informational text to help students refine their model as a group. Andy said, “The reading just provided more information so that would provide another piece of evidence that they could use to back up their evidence based discussion.” Similarly, Santana said that she had students “read through the articles, find what [is] evidence for these reasons, and discuss the evidence.” As Chanel indicated, instructional design matters; teachers need to “feed students information for them to revise their model.” It is through talk that students are able to work together to revise their models based on new evidence which opens up opportunities for evidence-based reasoning discussions.
Modeling Process Leads to Discussion

Findings from this study indicate that teachers think modeling helps students clarify and share their thinking, listen actively, and help students engage in deeper reasoning. As shown in Table 8, seven (8) teachers also indicated that models helps students engage in discussion.

Modeling leads to argumentation. Teachers indicated that modeling gets students to challenge each other. Sunny described how models help students engage in a Socratic Seminar discussion:

That’s the trigger, when somebody starts to disagree. Because all of the students were, “I thought we were in this together! I thought we were all going to agree, and it was going to be over fast, and then we were all going to get to go back to our seats and not pay attention for the rest of the class. Why are you disagreeing with me? Why are you saying that?

Biron, also said modeling was a way for students to challenge each other. Biron said, “I think it's just sharing ideas with each other and making them public so that you can have your ideas be challenged.”

Students learn from each other. Four (4) teachers said that the group context of the modeling unit opened up opportunity for students to learn from each other. Mike emphasized the value in allowing students to collaborate on their models. He said, “Students are really being responsible for their own learning.” The collaborative spirit of modeling opens up opportunities for students to discuss ideas in ways that build their content knowledge.

Modeling mirrors the work of scientists. Two (2) teachers (Santana and Cristine) reflected on the importance of replicating how scientists work. Santana said, “Science is not an individual activity. Science involves a lot of people.” She elaborated on how modeling affords a genuine group environment, emphasizing the importance of student-to-student interaction. Similarly, Cristine said that both she and her students valued the collaboration. While she
appreciated the small group work, she was the one teacher that pushed students to develop a class model because “knowledge is shared between three to four students. But once we were able to have a class model it’s like now 32 brains or 28 brains are put together to develop one model” which can lead to productive and meaningful class discussion. Modeling opens up opportunity for students to interact in the way scientists do, particularly in the type of discussions they have.

**Teachers’ Expression of Talk in the Context of Modeling is Process-Oriented**

Teachers’ perceptions of student talk, as they described it in a modeling unit, were all process-oriented. The subheadings in the previous section reveal this interesting process-oriented trend. They describe student talk as a tool for “communicating,” “explaining,” “clarifying,” “listening,” “questioning, “reasoning,” and, finally, “arguing.” The context of modeling helped teachers see the goal of student talk as part of the process for engaging in and learning content.

These process-oriented goals stated by teachers as the goal of student talk in a modeling unit display close alignment to the Science and Engineering Practices in the Next Generation standards. Their expressions about “communicating, explaining, clarifying, listening, questioning, reasoning, and arguing sound similar to Next Generation practices. The practices that my teacher participants articulated as student goals seem to align with the following Next Generation practices:  Practice #1: Asking Questions; Practice #4: Analyzing and Interpreting Data (evidence); Practice #6: Constructing Explanations; Practice #7: Engaging in Argumentation; and, Practice #8: Obtaining and Communicating Information.

**Summary of First-Year Teachers’ Goal of Modeling to Support Student Talk**

In summary, teachers were able to articulate much more descriptive responses to how modeling supports student talk in the context of modeling, which aligns to Next Generation language. First, all 10 teachers said that models give students the confidence to share their ideas
with one another, supports the explanation of content, and helps to clarify one’s thinking. These perceptions of modeling are aligned to Accountable Talk Goal #1 which states that “if a student is going to participate in the discussion, he or she has to share thoughts and responses out loud in a way that is understandable to others (Michaels & O’Connor, 2012, pg.9).” In addition, Accountable Talk Goal #2 says that students need to listen to others and try to understand them in order to contribute to the discussion” (emphasis added). Seven (7) teachers said that the collaborative nature of modeling requires students to listen to one another, thereby aligning to Accountable Talk Goal #2. Thirdly, the revision of models led to discussions that enabled deeper reasoning among students. Specifically, teachers said that the act of revising models deepens reasoning, is centered around evidence, and elicits more questions, a pattern aligned to Accountable Talk Goal #3. Finally, teachers said that collaborating with models engaged students in activities that replicate the way scientists work, particularly argumentation. The experience with modeling seemed to help open up opportunities for teachers to promote productive talk, thus being aligned to the Accountable Talk Goals. The next section investigates how these perceptions are realized in the classroom.

**How Talk is Realized in a Modeling Unit**

The previous two sections described teachers’ perceptions about the general goals for student talk and how modeling supported student talk. This section examines how teachers’ actual talk in the classroom related to the goals they expressed for student talk in their interviews.

I observed each teacher multiple times during the course of his or her modeling unit. During observations, I looked for instances of teachers using one of the nine talk moves identified as Accountable Talk (Michaels & O’Connor, 2012).
Context of Observation: Whole-Class Discussion

Classroom observation of whole-class instruction among these 10 teachers can be categorized as a *lecture* or a *discussion*. Lectures were one-way teacher-directed talk; discussions were explicitly two-way dialogue between the teacher and his or her students. Figure 4 summarizes the percentage of time each teacher was lecturing or facilitating a discussion during whole-class instruction.

**Figure 4: Percentage of Lecture and Discussion During Whole-Class Instruction**

![Bar chart showing the percentage of time each teacher was lecturing or discussing](image)

As seen in Figure 4, 4 teachers (Biron, Kevin, Sunny, and Cristine) engaged students in discussion 50% or more of the time during whole-class instruction, whereas 6 teachers (Andy, Kim, Mike, Sarah, Angel, and Santana) were lecturing for most of the whole-class instructional time. My observations focused on whole class discussions, as these are the contexts where Accountable Talk is intended to be used. This strategy enabled me to see how teachers used Accountable Talk to organize student discussions.

**Overall Frequency of Talk Moves Aligned to Accountable Talk Goals**

During classroom observations I tallied teachers’ use of talk moves during whole-class instruction. Figure 5 summarizes the frequency for each talk move across all observations and
teachers. As a whole, teachers were using the talk moves, some with more frequency than others. Upon close examination of the talk moves, however, there appears to be a tension between how teachers used the talk moves and the intended goal of each talk move as articulated by Michaels & O’Connor (2012). This section revisits what teachers said about the goal of talk, summarizes how teachers used talk moves to promote productive talk, and presents the various ways teachers used the talk moves, which may and may not be aligned to the Accountable Talk Goals.

**Figure 5: Frequency of Times Teachers Address Each Goal During Discussion**

![Frequency of Times Teachers Address Each Goal During Discussion](image)

**How Do Teachers Open Up Opportunities for Students to Clarify, Share, and Explain?**

Through analysis of interview data, teachers said that the goal of talk is for students to clarify, explain, and share their thinking, which aligns to Accountable Talk Goal #1. This section examines how first-year teachers put these ideas into practice. Specifically, I examine how first-year teachers use models to help students clarify and explain their thinking. Two talk moves (and variations of these talk moves), “Say more…” and “So, are you saying…?”, were tallied during whole-class discussion.

As shown in Figure 5, teachers exhibited high use of the “Say more…” and “So, are you saying…?” talk moves. While frequency of use varied among teachers, so did the way teachers
used these talk moves. Classroom observation data indicates that there were two distinct ways teachers used these talk moves. Evidence suggests that teachers used these talk moves to help students share and explain their ideas, as aligned to Accountable Talk Goal #1. Teachers also used these talk moves as a way to help students report ideas, which is not aligned to the purpose of Accountable Talk Goal #1.

**Opportunity for students to provide explanation.** Four (4) teachers (Kevin, Biron, Sunny, and Mike) used the “Say More” and “So, are you saying…?” moves to help students share and explain their thinking to the class, thereby aligning to Accountable Talk Move #1. Teachers asked questions and elicited responses in order to open up opportunities for students to explain their thinking. In order to help students deepen their explanation, teachers had to press students for evidence. Kevin’s use of these talk moves is presented to illustrate how teachers helped students explain their thinking. In this example, Kevin is discussing lab observations with his students.

Kevin: Our goal today is to develop a model. The most important goal is to develop an explanation. In all actuality, you have all the info you need to explain this. Take time to write your explanation at the atomic level.

(Students are working on their model in groups. There is a lot of talk among students).

Kevin: (As students are working in groups) Students, focus on explanation!

**Whole class setting:**

Kevin: Danielle, would you like to share the explanations you discussed?
Student: It creates a layer that separates object from liquid.
Kevin: Why?
Student: The different solutions.
Kevin: Gonzolo?
Student: The molecules get into contact with each other.
Kevin: And then what Gonzolo?
Student: The liquid glides off.
Kevin: So liquid glides off? And?
Student: Water neutralizes the reaction.
Kevin: So you think…
Student: I think oil and water don’t mix.
Kevin: So you think oil and water don’t mix; what does this have to do with it?
Student: Superhydrophobic substances have charge.
Kevin: So, it has a charge?
Student: Superdense.
Kevin: What do you mean by “superdense”?

After this exchange, Kevin asks students to revise their model. In this excerpt, Kevin explicitly asks students for their explanations. Once a student responded, he rephrased their response. In order to probe further into what a student shared, he said, “And then what?” And because he is not satisfied with one student’s response – “oil and water don’t mix” – he asks, “So what does that have to do with it?” He also said, “What do you mean” and “So you mean…” in order to help students further explicate their thinking. This example typifies how the teachers used those talk moves that align with the purpose and intent of Accountable Talk Goal #1.

**A way to report ideas out.** Rather than helping students explain their thinking, which is the intent of the “Say more…” and “So, are you saying” talk move, 6 teachers used these talk moves to invite students to report ideas out. They moved from student to student or group to group as a way to have students share their models. While they used the “Say more” and “So, are you saying…?” talk moves, there was no evidence that they tried to help student explain their thinking. They did not press students for further explanation. The way Santana used talk moves is typical of what was observed among the teachers that use these talk moves to have students report ideas out:

Santana: Ivan, can you explain your drawing to the class?
Ivan: The drawing is a rainy day. The student will get sick because it is cold.
Santana: So the child will get sick because it is cold. Does anyone in the group have anything to add? Okay… Danny please explain your drawing.
Danny: The drawing is about coughing on your hand and getting sick
Santana: So if someone sneezes in your hand you can transfer, is that what you said? Anything else? Andrew, you are next.
Andrew: Germs are on hands and germs are on doorknobs.
Santana: So how does disease spread?
Andrew: Germs on hands will jump to hands and get on someone else.
Santana: Table 4? Alejandro.
Alejandro: I drew a guy drinking expired milk.
Eric: The sick man has a cold and the other man is about to pass him and sneezes on him, making the other man sick.
Santana: Anyone else?
Student F: The man gets sick because he talks to another person.

After this exchange, the class period ends. Santana does not revisit the group models the following day. Throughout this exchange, Santana is in front of the classroom and asks students to share their models. A representative from each group responds. She used “Please explain” to invite students to share their thinking. She asked students to “Say more” about their response and also paraphrased with “So, are you saying…?” but she did not elicit students to elaborate on their explanation as does Accountable Talk Goal #1.

**How Do Teachers Open Up Opportunities for Students to Listen to One Another?**

Interview analysis, as shown in Table 2, shows that 7 (Andy, Angel, Biron, Kevin, Mike, Sarah, and Sunny) of the participating first-year teachers say that modeling helps students “listen carefully with one another.” This section will examine how this perception is realized in the classroom. Because the talk move associated with Accountable Talk Goal #2 is “Rephrase and repeat,” classroom observations tallied this talk move as well as other ways teachers opened up opportunities for students to listen to one another. A tally of talk moves during whole-class discussion shows that a total of 8 teachers engaged students in active listening with and about their models. The intent of Accountable Talk Move #2 is to help students listen in order to help contribute to the discussion; however, teachers used “Listening” as a classroom management tool. Only 2 teachers showed indication of trying to build a culture of active listening in ways
that contributed to a discussion. All teachers also had students present to the class with the expectations that students listen carefully to one another.

**Ensure students are paying attention.** While the goal of the “Rephrase and repeat” talk move is for student to pay close attention to one another in order to contribute to the discussion at hand, all 10 teachers used the “Repeat or rephrase” talk move as a classroom management strategy. For example, after giving a set of instruction to students, Kevin asked one student, Can you explain what we are doing?” to see she was listening to instructions. And in order to ensure students were listening to each other, Mike asked another student to “Paraphrase what was said?” He deliberately asked the disengaged students to repeat what another student said. While classroom management is an important part of facilitating classroom discussion, teachers in this study dominantly use the listening talk move in ways that were not aligned to Accountable Talk Goal #2, and therefore did not contribute to discussion.

**Develop culture of listening.** Two (2) teachers (Biron and Sarah), however, exhibited evidence of using the “Repeat and rephrase” talk move embedded in a classroom conversation. Biron uses the “Rephrase” talk move to emphasize a point he is trying to make and help students participate in discussion. Prior to this discussion, students watched a short video and developed a model to illustrate what they thought a running man experiences physiologically.

Biron: Draw a model of how human and animal manage heat.
      (Students working in groups to draw a model).

**Whole-group setting:**

Biron: Let’s discuss. What is the difference between man and kudu?
Student: As he runs, he loses sweat, which keeps you cool; so need to drink
Biron: Can I get someone to rephrase what Angel just said?
Edgar: He was sweating so he had to replenish.
Biron: How?
Edgar: Drank water.
Biron: Why was he sweating?
Student: Running, hot.
Biron: So what was happening? That’s when the sweat happens. Someone else?
Student: Well, we agree that human body can release heat by body fluid. For kudu, they have no resources to expel heat. So only mouth. So heat release is slow.
Biron: Can someone rephrase this? The difference between how humans and kudus release heat?
Student: Human can get rid of heat faster?
Biron: And what example did he use?
Student: Different ways animals release heat. Anyone else?
Student: Humans sweat to cool down body…muscle work hard, heart rate increases, lung uses more oxygen.
Biron: Can someone repeat one thing?
Student: Systems are involved.
Biron: Let’s work on class model. What did you hear in this discussion?

As is evident, the teacher is facilitating a discussion about students’ prior knowledge. He is eliciting student responses and, along the way, if there is a point he wants to emphasize, he asks someone to “rephrase.” He also asks a student to rephrase something another student says, again to emphasize a point that can add meaning to the discussion to move it forward. Both Sarah and Biron show evidence that they use the talk moves as intended.

Presentations. All teachers in this study integrated small group presentations into their unit. This was a way to help presenters share their knowledge as well as have the audience listen. Eight (8) teachers told students to listen carefully so that they can ask questions about the models that are being shared. For example, Sarah had each group present their group model of photosynthesis to the whole-class. She instructed students to listen carefully and asked questions to the presenting groups. Upon reflection she said she wanted students “to listen to what their classmates are saying about their models, and have them respond to that.” Each presentation was followed up by at least four questions which required close listening skills on the part of the students in the audience because it was intended to be a student-centered conversation.

Angela also had students present their models of the solar oven. She opened up
opportunities for students to engage in active listening: “I can't help but go back to the presentations that they did. I was very impressed. The part that stood out to me the most was when the students were asking questions, and they were answering their questions at the very last part.”

These presentations helped students to report out. The back and forth questions between presenter and listeners, however, was evidence that students were actively listening. Teachers’ intention in setting presentations up this way is evidence that they want students to listen in order to contribute to a discussion.

**How Do Teachers Promote Deeper Reasoning?**

Even if students are able to share their thoughts and listen carefully to one another, Michaels et al (2012) said that the discussion can still fail to be academically productive. Students need to engage in “solid and sustained scientific reasoning” (p. 9), wherein they are pushing to understand and deepen their own reasoning. The two talk moves that support Accountable Talk Goal #3 are “Asking for evidence or reasoning” and “Challenge or counterexample.” Upon classroom observation, two distinct categories of teachers emerge: teachers who asked for evidence as a “check for understanding,” and teachers who asked for evidence to deepen reasoning.

**Checking for understanding.** While all teachers use the “asking for evidence” talk move, 5 teachers (Kevin, Mike, Santana, Cristine, and Angel) used this talk move as a “check for understanding.” These teachers asked for evidence to ensure students understood the lab or made the correct observations. Rather than engaging in a discussion, these teachers were looking for the right answer. The example of Kevin, presented below, typifies how these teachers debrief a lab:
Kevin: Let’s go through each station. Who did station A?
Student: I observed that water is sticky and when you put it in pipette, water goes down because of the forces.
Kevin: Because of capillary action? Who did station B?
Student: We observed cohesive and adhesive?
Kevin: How did you observe?
Student: By observing number of drops on penny of water and alcohol.
Kevin: What did you observe in station C?
Student: I observed oil and alcohol do not mix.
Kevin: So you observed that oil, alcohol, and water do not mix. Station D?
Student: We put salt and sugar into water, alcohol, and oil.
Kevin: What were your observations?
Student: They dissolve in water.
Kevin: Why did it dissolve in water.
Student: We observe that paper does not float.
Kevin: Why?

In this example, Kevin asks students “what they observed” and “which did it dissolve in” and is looking for one right answer. He proceeded to go around the class and see what they observed without asking students to build on the presented ideas, an omission which does not build students’ reasoning.

Similarly, Mike is asking students about findings from their text-based research. In this example, he is asking very specific, content-based questions that do not support reasoning:

Mike: What did you find doing your research?
Student: Different types of UV.
Mike: How many different types?
Student: Two UVA and UVB...
Mike: And?
Student: UVC.
Mike: Yes UVC as well.
Mike: What do you know about these?
Student: UVA is longer, UVB is shorts and…
Mike: Which one causes cancer?
Student: ---silence---
Mike: Maybe we need to investigate more?

Evidence used to build reasoning. Conversely, 2 teachers (Biron and Sunny) asked students for evidence in order to deepen their reasoning about the content at hand. Similar to
Kevin’s conversation, this exchange took place after a lab:

Sunny: Today, we want a model that reflects all your experiences; let’s see how your models changes. What happened to the water in your salt lab?
Student: It changed.
Sunny: How does it change?
Student: The water changes.
Sunny: So, how does it change?
Student: It got wet.
Sunny: So, what got wet?
Student: Salt got wet.
Sunny: So what happens when salt dissolves in water?
Student: It combines.
Sunny: Okay, combines; what do you think was happening to water molecule?
Student: It was combining.
Sunny: So sticking together... Okay, some say water is sticky.
Student: No.
Sunny: What defines “sticky”?
Student: Like oil.
Sunny: Why is oil sticky?
Student: It sticks.
Sunny: Try to explain what sticky is.

In this excerpt, Sunny asked students “what happened” and “how” to elicit deeper thinking skills. She followed up on this lesson by having students go back to and revise their models. She was connecting the evidence from their lab to deepen their understanding of content, which is aligned to Accountable Talk Goal #3.

How Do First-Year Teachers Facilitate Student-Centered Discussion?

The fourth goal of Accountable Talk is described as “students actually taking up the ideas and reasoning of other students and responding to them” (Michaels et al, 2012). Interview responses in section two of this chapter revealed that 7 teachers said modeling helps students address Accountable Talk Goal #4. These teachers specifically said models help students reason with one another as they build consensus on group and whole-class models.

The talk moves that helped teachers address Accountable Talk Goal #4 are: 1) do you
agree, or disagree and why; 2) add-on; and, 3) explain what someone else means.

Evidence from classroom observation suggests that all teachers used the “add-on” talk move, which was that with the highest frequency across all teachers combined. As with all the talk goals and talk moves, teachers used the talk move associated with the goal that did and did not align to the intent of the talk goal.

**Student-to-student talk.** One (1) teacher, Sunny, was able to use models to engage students in whole-class discussion. At the end of her unit, she had students engage in a Socratic Seminar with and about their models. When I asked her about the most successful talk moment, she described the Socratic Seminar:

I felt like I was most successful in getting students to talk to each other at the end—I mean, on the big discussion day—because there were small disagreements. The small disagreements. They start off thinking … The students start off, and what happens in almost all discussions is they just say, “Oh, I agree with so-and-so, because da-da-da-da.” But then they realize they’re saying different things, and that’s the most entertaining and engaging part of any discussion. A lot of times paraphrasing, doing paraphrasing statements, “What you’re saying is this?” and they’ll be “No … Wait … That’s not what you … Oh!” They do this process where they realize “I don’t agree with everyone! Why don’t we agree? I have to convince them to my side!” It’s like a switch that flips.

**Teacher-centered talk.** Besides Sunny, all observed classroom talk was teacher-centered. The transcripts that were presented in the previous sections illustrate this. In all excerpts, teachers initiated, students responded and teachers evaluated the responses. This IRE pattern of discourse dominated instruction. This pattern of discourse is not aligned to the vision of Accountable Talk.

**Summary of How Teachers Promote Talk in a Modeling Context**

Upon classroom observation, all teachers opened up opportunities for students to engage in talk. This study examined how teachers promoted productive talk whole-class discussion.
Figure 6 presents raw data on the frequency of use for each talk move across all teachers.

**Figure 6: Frequency of Talk Moves Across All Teachers**

While Figure 6 illustrates variability in the frequency of talk moves, there is a clear distinction between the types of talk moves that exhibit high frequency and ones that have low to no usage. The “say more,” “so, are you saying,” “who can rephrase,” “asking for evidence,” and “add-on” are all talk moves that take place between teacher and student – these have high frequency. “Challenge or counterexample,” “agree/disagree and why?” and “explain what someone else means,” however, show comparatively low frequency. These talk moves involve students to build on the ideas of other students, which requires teachers to create dialogue between students.

During the interviews, teachers expressed that certain talk moves were more difficult to use. Andy said, “I think that giving, agreeing, disagreeing, and challenging are harder for them to do and I think maybe they need to get used to them talking first. It is even difficult for adults. I felt more comfortable in using certain talk moves.”

Overall, teachers seem to use the talk moves that they are more comfortable with. Upon observation, these are the elicitation and elaboration talk moves. Teachers also exhibit low use of
the talk moves they consider to be difficult. This discrepancy and the implications of this
discrepancy will be discussed in the next chapter.
CHAPTER 5: DISCUSSION

The discourse demands of the Next Generation Science Standards are significantly different from the current California State Standards. This shift will have implications for how students learn and, consequently, how teachers learn. This study examined first-year teachers’ perception of student talk and their uptake of modeling as a way to promote productive talk.

Findings suggest that modeling gave teachers a richer context to consider the purpose of talk, thereby aligning to the Science and Engineering Practices in the Next Generation Science Standards. This study also found that teachers gravitate toward talk moves aimed at elicitation and elaboration of student thinking, which contributes to the teacher-centered talk that characterizes nine out of the ten classroom discussions observed in this study. After presenting a discussion of findings, I share limitations of the findings, recommendations based on the findings, and possible future research opportunities.

Modeling Gave Teachers Richer Context to Consider the Purpose of Student Talk

The findings in this study illuminate how teachers perceive the goals of student talk. While their expression related to the goals of student talk in general is tied to assessment, their response about the goals of student talk in a modeling unit is much more process-oriented.

Because modeling provides a rich context for talk to take place, the way teachers describe the purpose of talk to support modeling is markedly different from the way they describe student talk in general. When asked about the goal of student talk in general, they describe its assessment value. For example, teachers said that talk reveals student understanding by “making their thinking visible.” They also communicated that talk helps students learn science concepts.

This limited perspective of talk, however, may have been due to the placement and
general nature of the interview question. I asked teachers to articulate the purpose of student talk as the first part of the interview. Nevertheless, teachers’ expression about talk did not align to the goal of talk as expressed in the Accountable Talk Goals. Accountable Talk is coined “accountable” because the idea is to keep students accountable at three levels: to their learning community, to knowledge, and to rigorous thinking (Michaels et al., 2008). I will come back to this idea again later; for now, teachers’ expression about the goal of student talk is focused on keeping students accountable to knowledge, i.e., their responses to the general question about talk is not connected to keeping students accountable to their peers (community) or to rigorous thinking.

As the interviews progressed, teachers had an opportunity to reflect on their modeling unit. Thereafter, teachers were asked again, to articulate the goals of student talk. This time, teachers expressed the goals of student talk in the context of their modeling unit, which led to richer responses.

Across all interviews, teacher responses were markedly different. Similar to the general question about the role of student talk, teachers articulated the benefit of assessing student understanding through talk. They indicated that they were able to formatively assess student learning through talk, models, and through talk about models. However, in addition to student talk as an assessment tool, another interesting pattern for the goals of student talk emerged. As described in Chapter Four, the expressions that teachers used to describe the goals of talk were all process-oriented, similar to the language of the Science and Engineering Practices in the Next Generation Science Standards.

These process-oriented goals stated by teachers as the goals of student talk in a modeling unit display at least some alignment to Science and Engineering Practices in the Next Generation

**Purpose of talk is to ask questions.** Teachers indicated that the purpose of student talk in a modeling context is for students to ask questions. They said that as students work with models to make sense of content, they ask more questions. This perception is aligned to what research says about generating questions as a fundamental way to build content knowledge in science (Carey & Smith, 1993; Lederman, 2007; Lehrer & Schuble, 2006). Specifically, Schwarz (2009) says “model changes are considered to develop questions that can then be tested against evidence.” As student models evolved, teachers indicated that students had to question why and how their models changed. These types of questions, however, should come from students in order to deepen their inquiry and learning.

Students developing questions is the first science and engineering practice listed in the Next Generation Science Standards. Much like this example, students will have to produce their own questions. This study indicates that modeling can scaffold this process in ways that contribute to student discussion.

**Talk as Analyzing and Interpreting Data.** Teachers expressed one goal of talk as an opportunity for students to discuss the merit of evidence and how evidence might support their reasoning. In a modeling unit, this was foundational to advancing group models. Students had to work with one another to analyze how data and evidence might fit their argument, which in this case was in the form of a model. Neilson, Campbell, & Allred (2010) said “through iterations, students connect emergent evidence and explanations to their broader understanding of content” (p.1). The act of analyzing evidence to see if it supports ones claim or model helps to deepen student understanding of content. The modeling process invites students to engage the analysis of
data multiple times in order to modify their models. Hence, the iterative process of revising a model is dependent on students’ ability to analyze and interpret data. This is clearly one of the Science and Engineering Practices, which states that “a major practice of scientists is to organize and interpret data in ways that bring out the meaning of data—and their relevance—so that they may be used as evidence.” According to participating teachers, models help students assess the value of their data and how it may contribute to their general argument.

**Talk as constructing explanations.** Teachers also said that a goal of talk is to explain ideas to one another. They indicated that models help students construct and communicate information to one another. Because science is about explaining the natural world, it is important to help students develop tools and strategies to explain phenomena. Teachers expressed similar sentiments as Krajcik & Merritt (2012) who said, “Models provide a powerful tool for explaining phenomena,” meaning that models help students articulate their ideas both verbally and visually. Teachers also said that models enhanced students’ ability to explain their ideas to one another. They indicated that the tangible nature of models helped students articulate their ideas to their peers. Furthermore, models opened up multiple opportunities for students to construct and communicate their explanations. The Framework for K-12 Science Education, which articulates the new vision for science education, states the following about explanation:

> Asking students to demonstrate their own understanding of the implications of a scientific idea by developing their own explanations of phenomena, whether based on observations they have made or models they have developed, engages them in an essential part of the process by which conceptual change can occur.

The goal of talk as a means to construct explanations is clearly articulated by all teachers, a clear goal of Next Generation. They also indicate that models support students’ articulate explanations in order to move discussion forward.
**Talk as argumentation.** Seven teachers emphasized that another goal of talk in science was to engage in argumentation. They said that science was about “taking a stance” or “having an opinion and standing by it.” The modeling context, as teachers indicated, provided a concrete reason for students to engage in argumentation. For instance, developing a group model required that students work through disagreements and build consensus. Students had to take up evidence, discuss the merit of the evidence and build consensus on how the evidence might enhance or modify their model. Recall that this is an explicit part of the modeling process. As Passmore & Svoboda, (2012) said, modeling “provides a way to anchor argumentation to various phases of scientific inquiry,” by which they mean students have to negotiate and build consensus by examining the evidence presented by their peers.

Argumentation is aligned to what Next Generation Science Standards says, “students should argue for the explanations they construct, defend their interpretations of the associated data, and advocate for the designs they propose (NRC, 2012, p. 73). Research indicates that this is a very challenging practice (Driver et al., 2000; Duschl & Osborne, 2002; Osborne et al., 2004). This study, however, indicates that models provide a scaffold for teachers to help students reason with one another’s idea, examine evidence thereby developing argumentation skills.

**Talk as communicating information.** Teachers articulated one goal of talk as an opportunity for students to share ideas. This goal was stated when teachers were asked about student talk in general. However, when teachers considered the goals of student talk in a modeling unit, their expressions were more detailed. For example, each teacher referred to the concepts being taught and described the way students communicated their concepts. They also indicated that the modeling unit opened multiple opportunities for students to communicate, both in large and small groups. Schwarz et al., (2009) also said, “Models can be used to help scientists
and learners to generate new understandings or to communicate their understandings to others.”

As the NRC (2012) states in its Framework, “Communicating information, evidence, and ideas can be done in multiple ways: using tables, diagrams, graphs, models, interactive displays, and equations as well as orally, in writing, and through extended discussions.” This study focused on students’ ability to communicate using a model.

In summary, the rich context of modeling helped teachers re-conceptualize the goals of student talk—they articulated more goals and outcomes for talk in their responses. These responses aligned to six of the eight Science and Engineering Practices. This illuminates a recommendation that will be discussed later.

**Teachers Gravitate Toward Elicitation and Elaboration Talk Moves**

Classroom observation reveals a distinct pattern in how teachers’ appropriate talk moves to facilitate discussion. As presented in chapter four, teachers exhibit a high frequency of elicitation and elaboration talk moves. These talk moves include, “say more,” “so, are you saying…?” “who can rephrase?” and “add on.” The teachers in this study used talk moves keep students accountable to the teacher as teachers ask the question and students respond directly to the teacher.

Conversely, this study found that teachers do not use the talk moves “agree, disagree and why,” “challenge or counterexample,” and “explain what someone else means.” In addition to the difficulty factor, these talk moves are different from the elaboration talk moves in that they require students to be accountable to each other. The “agree, disagree and why” and “challenge” talk move is particularly challenging as it presses students to be held accountable to rigorous thinking. Research indicates that supporting students’ explanations requires teachers not only to provide sufficient time and appropriate tasks but also to press for justification and explanation in
response to student performance (Kazemi & Stipek, 2001; Silver & Smith, 1996; Stein, Grover, & Henningsen, 1996). Upon students’ initial response, it is important to push students to think deeply about their claim, evidence and reasoning. Often times, this requires students to press students for these connections.

By utilizing all nine talk moves, a teacher can move beyond eliciting and elaborating toward pushing students to build on the idea of others and press students for deeper reasoning. These combined will help students be accountable to their community of learners, to knowledge and to rigorous thinking.

In summary, across the nine talk moves that support the four Accountable Talk goals, teachers latched onto the moves that ask students to share and elaborate on their thinking, as these are easier to use. Furthermore, teachers stayed clear from using the talk moves that are more challenging. Yet, it will be important to notice and practice the talk moves that are more difficult, as these are the ones that embody what the Next Generation Science Practices and goal for talk is.

**Teacher-Centered Talk in Student-Centered Learning Environment**

The vision of science education, as defined in the Next Generation Science Standards, is for science classrooms to be student-centered. The goal of Accountable Talk is not only that students to engage in productive talk, but that they engage in student-centered discourse. This study was organized around model-based reasoning, a student-centered approach to science. Students work with one another to collaborate and learn. While the setting of this study (modeling and talk) is student-centered, all but Sunny’s class, was centered around the teacher.

As mentioned in the previous discussion point, first-year teachers are fluent and flexible with the elicitation and elaboration talk moves. These talk moves play out in classrooms that are
typical of the I-R-E sequence of teacher talk: Teacher initiates with a question, students responds, and teacher evaluates response (Cazden, 2001). Upon close examination, these teachers’ current use of the accountable talk moves reflects that the authority and thus the accountability lies with the teacher, rather than the students, which is contrary to Accountable Talk and the vision for Next Generation Science Standards.

While nine teachers from this study predominantly facilitated class discussion using this pattern of discourse, Sunny, as described in chapter four was able to remove herself from the center of the conversation, opening up an opportunity for student-centered discourse. In order to take herself out of the conversation she prepared the room for the discussion by writing “I agree because …”, “I disagree because …” on the board to prime the discussion. She described how the student-centered discourse she envisions took place.

Sunny, as a first-year teacher, was able to engage students in student-centered discourse through Socratic Seminar. She intentionally provided sentence starters on the board to support student-centered talk. By observing one class period of Socratic Seminar, I was able to see evidence of students being held accountable to their peers, to content knowledge and to rigorous thinking. This illustrates ambitious teaching can be found in first-year teachers. Hence, recommendations for teacher-preparation programs will be shared below.

**Limitations**

It is important to note the limitations of this study. While this study provides some insight into the way first year teachers conceptualize and enact talk during classroom talk, the findings are not generalizable. This study took place in a single site and had a very small sample size of ten teachers.

The findings from this study provide insights into ways teachers promote student talk.
However, the findings may be confounded for two reasons. First, because this study took place the first-semester of instruction, many factors on how teachers teach impact their practice. Secondly, these first-year teachers taught a modeling unit for the first time. The novel approach may have impacted the way teachers actually facilitate classroom discussion.

Finally, this study took place over approximately three periods of instruction and only gave a snapshot of instruction that may or may not have been reflective of teacher practice.

**Recommendations**

Findings from this study indicate that teachers continue to be at the center of instruction. Analysis of teacher talk moves also indicate that teachers are using elaboration and elicitation talk moves to promote talk. The pattern in which teachers use talk moves indicate that they are not addressing the goal of holding students accountable to their peers—they focus on the elaboration and elicitation talk moves. While the goals of Accountable Talk are to keep students accountable to their community, knowledge and rigorous thinking, evidence from this study suggests that teachers have a limited understanding of the Accountable Talk framework. With the goal of promoting student-centered talk that is aligned to both the Next Generation Science Standards and to Accountable Talk Goals, this study offers four recommendations.

**Focus on Talk as a Way to Learn Next Generation Standards**

The shift towards the Next Generation Science Standards will require professional developers and teacher educators to understand how to best support teacher understanding of Next Generation. Shifting practice to be aligned to Next Generation is a challenging endeavor and will require an overhaul on the way teachers teach. Because of the overwhelming nature of the shift, teachers need to prioritize the parts of Next Generation to explore.

As discussed earlier, teachers’ perception of talk in the context of modeling is aligned to
a majority of the Science and Engineering Practices (SEPs). When students are talking with and about their models, they are engaging in SEPs. The recommendation, based on this study, is to deepen teachers understanding of productive talk. And by having students engage in productive talk, have teachers reflect on the Next Generation SEPs that students are engaging in.

**Revision of Science Observation Rubric**

The observation rubric that was utilized by the faculty advisor (Appendix C) focused on: teacher questioning, teacher facilitation of discourse, and level of student discourse. The category called “teacher questioning” looked at the level or rigor for the questions that teachers were asking. The teacher facilitation category analyzed the “participation structures.” And finally the student discourse category looked at student use of evidence to support understanding of content. As described, all three areas of focus stay within the realm of keeping students accountable to the knowledge. This rubric did not assess how teachers help students engage in talk that is productive to their peers or to rigorous thinking. If our goal is to move students to move toward student-to-student interactions, this classroom rubric will need to revised to reflect ways to support more student-to-student interaction in a whole-classroom discussion setting.

I recommend that classroom observations should look for ways that teachers keep students accountable to their community, rigorous thinking and peers. This way, teachers will be more mindful of and therefore integrate discourse that is more aligned to Accountable Talk Goal #4.

**Develop Deeper Understanding of the Accountable Talk Framework**

As described in chapter four, teachers used the talk moves in ways that were not aligned to the goals, which illustrates teachers’ limited understanding of the Accountable Talk Goal Framework. Leinhaardt & Greeno (1986) say that “teachers who engage in competently adaptive
complex performance rely on a repertoire of routines that are informed by a vision of the goals to which these routines must be met,” which means that teachers need to have a deep conceptual understanding of the strategies and moves they use; or this study suggests, teachers will use the strategies and miss the goal of the intended strategy. Teachers in this study seemed to rely on the talk moves without understanding the underlying vision. Their use of talk moves did not align to the intended purpose. Therefore, Ghousseini, Beasley, & Lord (2015) say novice teachers must have opportunities to both to practice using enactment tools, like the talk moves and to appropriate a framework of goals in order to develop their adaptive capacity. I highly recommend that teachers understand the big idea related to Accountable Talk prior to practicing the strategies. This understanding will have implications for the way professional development and teacher training is realized.

Rehearsal

One of the themes in this study is teachers’ gravitation toward and use of elicitation and elaboration talk moves. Because teachers focus on these moves, students are engaging in talk with the teacher and thereby missing the goal of student-centered discourse as envisioned by Accountable Talk altogether. Interview responses indicate that teachers find the other talk moves challenging. In fact, Cristine said she’d like more practice with using these challenging talk moves. Which brings us to my final recommendation: rehearsal of talk moves.

Rehearsal can involve novices in publicly and deliberately practicing how to teach rigorous content to particular students using particular instructional activities. It can provide a setting in which teachers rehearse pedagogical strategies (Lampert, Ghousseini, & Beasley, 2011; Lampert & Graziani, 2009). Ghousseini et al. (2015) illustrate how a well-specified question sequence can be used in the context of rehearsal to create opportunities for novices to
deliberately practice a core aspect of ambitious teaching: eliciting and responding to student thinking. For teachers in this study, a rehearsal on talk moves, particularly the challenging ones would provide practice and feedback in order to increase their flexibility with the talk move. Ghousseini et al., (2015) says, “multiple enactments and analyses, the beginners learn which aspects of the structure of instruction remains relatively constant or “routine” and what parts of their performance need to be adjusted to what students know, what they are learning, and what they still need to understand and be able to do.” Upon reflection, teachers in this study indicated that they would have liked more practice using the talk moves.

**Future Research Opportunities**

As the nation transitions into the Next Generation Science Standards, it will be critical to understand how to best train teachers as they learn how to open up opportunities for student-centered discourse. Future research on how to support teacher development of talk will be important to the success of the current education reform our nation is facing. There are four possible future opportunities that can contribute to this area of research.

First, this study examined the perception of student talk among ten teachers. This small sample, as mentioned, is not generalizable. Yet it gave us some insights on teacher limited understanding of the goal of student talk. It revealed that teachers have varied interpretations and depth of knowledge related to the goal of student talk. In order to generalize the findings to this study, a national study of how teachers perceive student talk would provide deeper insights on how to better prepare teachers for the language demands of the new standards. An understanding of the variations in which teachers conceptualize talk will contribute to the design of professional development.

This study investigated how teachers appropriate talk through model-based instruction.
The models presented certain benefits that helped teachers open up opportunities for discourse. An interesting area of research might be in studying other pedagogical approaches to opening up student talk. This will add the repertoire of ways teachers can promote student talk. In order to learn about the different pedagogical approaches, I recommend observing large number of classrooms to identify the pedagogical strategies teachers are using to promote student talk. This will provide insights into what teachers are already doing, what is working and what is continuing to perpetuate the teacher-centered talk that is seen in classrooms today.

While the findings from this study is tied to a teacher preparation course, it has relevant implications for teacher professional development. With such a heavy focus on discourse, it will be important to identify the professional development practices that lead to increased student-centered talk. Research on identifying best professional development practices can have lasting impacts on how to train teachers.

**Final Remarks**

Research shows the importance of student talk. This is now reflected in the standards, the Next Generation Science Standards emphasizes learning through talk. As this study describes, however, promoting talk as envisioned by Next Generation Science Standards is very challenging. We must move away from teacher-centered instruction toward student-centered learning, requiring significant shifts in teacher preparation and teacher professional development. This challenge will be one that educators as a whole will need to consider.
APPENDICES

Appendix A: ED 498 Syllabus

ED 498A/B Directed Field Experience
Fall Quarter 2014

Course & Instructor Information:
ED 498A/B Directed Field Experience 8 units, Letter Grade
Hours and Times: M-F Location: Field
Instructors: Imelda Nava, Ph.D. and Jaime Park, Ph.D.; inava@ucla.edu, japark@gseis.ucla.edu
Office: 2030 Moore Hall Office Hours: By Appointment

Course Description:
Residents engage in field experiences designed to increase understanding of student learning and teacher practice. Residents engage in instructional strategies introduced in the Novice Year to further develop understanding around how the strategies leverage student learning: high-level tasks, concept maps, questioning, think-pair-share, KWL chart, word wall, receptive/kinesthetic assessments, reflective closings, feedback & community circles. Residents are employed by local school districts and teach in designated school sites with racially, culturally, and linguistically diverse student populations. Residents also work in collaborative teams striving to become transformative educators through initiating change in schools and acting as agents of change in the communities.

Required Course Texts, Websites and Materials:
1) Content Standards: The CA ELD Standards; The Common Core State Standards http://www.corestandards.org; The Next Generation Science Standards http://www.nextgenscience.org/next-generation-science-standards; Course CCLE Website to upload assignments and weekly reading posts
2) Books:
Reflective Educators Guide to Classroom Research by Nancy Fichtman Dana and Diane Yendo-Hoppey
Culture and Power in the Classroom by Antonia Darder

Course Assignments and Grading Criteria:
➢ Attendance and Punctuality to class meetings and events.
➢ Preparation for class. Completion of readings and written assignments, particularly CCLE posts, prior to class. Completion of all assignments
➢ Participation during class. An important aspect of any classroom learning community is the active engagement of students and teachers.

1. Unit Plan (20%) – Residents will submit a unit plan they will teach in the Fall quarter. Lynn Kim-John will assist in the development of a model-based reasoning unit.

2. Lesson Plan Portfolio (20%) - Residents will use their preferred template to create lesson plans for the class they will conduct their inquiry in. Select 5 exemplar lesson plans.

3. Video Portfolio (See ED481/490A) - Residents will create 5-10 minute video clips capturing core-teaching practices related to the Master’s project. Residents can use Zaption.com, Youtube.com or a
preferred online platform to store the videos. These videos will be used for instructional rounds. Residents are encouraged to show video clips during the Master’s project presentation.

4. **Teaching Journals (20%)** – Journaling is one powerful way to engage in critical thinking and reflection. Residents will maintain a spiral notebook in their classroom. Residents will write daily reflections about their developing teacher practice by raising questions and making connections. Residents will bring their journal to seminar and share their responses with colleagues for ideas and feedback.

**Potential Modes of Articulation and Learning for Debriefing the Field**

**Challenge of Practice: Table Talk Rotations** - Four people share their challenge of practice in rotations. There are 8 groups of 4. Each individual has time to present a challenge and then move to another group. If you have no person that presented a problem of practice, then you discuss the problem that just emerged. Document your recommendations for problems of practice.

**Challenge of Practice: Table Choice** - Four peers will share their problem of practice to the whole group, each taking 2 minutes. Then peers will select what challenge of practice they may want to engage more deeply with by sitting in 4 groups. The groups will present their questions and insights. The questions and insights will be documented and presented. The groups can engage in a protocol that includes participation opportunities to share issues, ask clarifying questions, take notes, and engage in reflections.

5. **CCLE Reading Posts (20%)** – Weekly reading posts and responses on CCLE allow Residents to engage in an ongoing reflection about their teaching practice and their developing teacher identity. There will be prompts for which the Residents will respond to on the CCLE. There will be the 1st Post and 2nd Post for the same reading. 2nd Post should be completed after reading others’ posts and further reflecting on the reading in relation to Residents’ inquiry focus and/or teaching practices.

6. **Preparedness, Attendance, Readings & Active Participation (20%)** – The purpose for this course is to support developing teachers study their practice. In order for this to happen, Residents will be asked to make their teaching practices visible through these various assignments, seek critical feedback and engage in critical dialogue with one another. Residents’ active participation in this teaching professional community is a major goal of this course design. Unexcused absences and tardiness may result in “I” incomplete, or a lower grade
# Appendix B: Interview Protocol

<table>
<thead>
<tr>
<th>Rationale</th>
<th>Question</th>
<th>Probing Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers reflect on Unit</td>
<td>1. How do you think the unit went?</td>
<td>a. Tell me why you think that.</td>
</tr>
</tbody>
</table>
| | 2. What were you hoping your students would get out of the unit you designed? | a. Content?  
b. Skills? |
| | 3. Do you think they learned X [from Q2]? | a. How do you know they learned X? |
| Identify teacher understanding of student-centered talk. | 1. What is your definition of student talk?  
2. What is the importance of student talk? | a. And, why might it be important for …[connect to teacher response] |
| Teachers reflect on Talk Moves | As you were teaching, I documented and tallied your use of Talk Moves.  
6. What do you see? | a. Do you see any patterns? Trends?  
b. Tell me a little bit about the thinking and planning that produced this pattern. |
| | 7. Reflect on your unit (and consider this frequency table) --do you believe your students were engaged in student-centered talk? | a. If yes, why do you think that?  
b. When, in the unit, did you feel most successful in promoting student-centered talk?  
c. If no, what would you change in your instruction?  
d. What might you need support in to do this better? |
| Teachers reflect on the use of Model-Based Reasoning to promote student-centered talk. | 8. What was the goal of talk in your modeling unit? | a. What was talk most successful?  
b. Most challenging?  
c. Why? |
| Reflect on Nees | 9. What further support might you need to promote talk? | a. What supports have been helpful? |
Appendix C: Classroom Observation Rubric

<table>
<thead>
<tr>
<th>CLASSROOM ROUTINES</th>
<th>LEVEL</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUPPORTING DEVELOPMENT OF ACADEMIC LANGUAGE</td>
<td>LEVEL 1</td>
<td>Communication and collaboration are valued and used. Teacher and students use observable classroom routines (lesson running, class running) that facilitate productive, safe, and positive learning environment.</td>
</tr>
<tr>
<td>LEVEL 2</td>
<td>Teacher and students use observable classroom routines that facilitate productive, safe, and positive learning environment.</td>
<td></td>
</tr>
<tr>
<td>LEVEL 3</td>
<td>Teacher and students use observable classroom routines that facilitate productive, safe, and positive learning environment.</td>
<td></td>
</tr>
<tr>
<td>LEVEL 4</td>
<td>Teacher and students use observable classroom routines that facilitate productive, safe, and positive learning environment.</td>
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</tr>
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</table>

<table>
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<tr>
<th>COMMUNITY OF LEARNERS</th>
<th>LEVEL</th>
<th>Rationale</th>
</tr>
</thead>
</table>
| SUPPORTING DEVELOPMENT OF ACADEMIC LANGUAGE | LEVEL 1 | Teacher and students are a community of learners. Social interactions and social norms that facilitate productive learning environment.
Teacher and students are a community of learners. Social interactions and social norms that facilitate productive learning environment. |
| LEVEL 2 | Teacher and students are a community of learners. Social interactions and social norms that facilitate productive learning environment. |
| LEVEL 3 | Teacher and students are a community of learners. Social interactions and social norms that facilitate productive learning environment. |
| LEVEL 4 | Teacher and students are a community of learners. Social interactions and social norms that facilitate productive learning environment. |

<table>
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<tr>
<th>DEMOCRATIC CLASSROOM</th>
<th>LEVEL</th>
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<th>EQUITABLE ACCESS TO CONTENT</th>
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<th>EXAMPLES OF INSTRUCTIONAL STRATEGIES</th>
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Developed by Jaime Park, Imelda Nava and Mollie Appelgate

UCLA Teacher Education Program
Appendix D: Informed Consent Form for Secondary Science IMPACT Residents

University of California, Los Angeles

CONSENT TO PARTICIPATE IN RESEARCH

Modeling to Produce Academically Productive Discourse

IMPACT Research Study Supplemental Study

You are asked to participate in a research study conducted by Lynn Kim-John, a graduate student in the Educational Leadership Program at UCLA, under the sponsorship of Prof. William A. Sandoval. You were selected as a possible participant in this study because you are part of the Secondary Science UCLA IMPACT Urban Teacher Residency program.

PURPOSE OF THE STUDY
The purpose of this study is to understand how to best prepare teachers to meet the discourse demands of the Next Generation Science Standards and the Common Core State Standards. During the fall of 2013, you participated in a Methods course that focused on modeling to produce effective classroom conversations. I am now interested in how you integrate modeling into your practice to engage students in effective discourse. This study will have the potential to inform teacher preparation (pre-service and in-service) in order to meet the language demands of the Common Core and the Next Generation Science Standards.

Please note that the purpose of this study is to evaluate the efficacy the IMPACT Methods course and is not intended to evaluate individual teachers. As the researcher, I am interested in the teaching practices of your cohort and will not be looking to analyze the teaching practice of individual teachers. Hence, your identity will be kept confidential throughout the study.

PROCEDURES
For this study, I am asking for your permission to collect and analyze data on teaching practices that promote student-centered discourse. The following research questions will guide the collection and analysis of data:

1. How do teachers use models to promote classroom discourse?
2. What do teachers say are the benefits and challenges of using models to promote student-centered discourse?

I am asking for permission to collect the following data from you:
• **Lesson Plans:** I would like to collect and analyze a unit that you will be teaching during the upcoming Fall Semester (2014-2015). I will be analyzing your lesson plans to understand the modeling strategies, if any, you utilize to promote student talk.

• **Classroom Observations:** I would like to observe a subset of teachers in your cohort. The subset will be identified and made up of teachers that plan to integrate modeling into instruction. I am asking permission to observe the subset of teachers 2-5 times throughout the Fall Semester (2014-2015). I will be using a classroom observation protocol to collect data on how teachers use modeling to promote discourse. Each observation will be scheduled in advance with the teachers. Each observation will last an entire class period and will not disrupt instruction.

• **Interview:** Finally, I am asking all participating teachers to engage in an interview. Each interview will be one-hour in length. I will work with each teacher to schedule the interview at a time that is convenient for the teacher—virtual interviews are also an option. I am asking permission to audio-record the interview.

**PARTICIPATION IS VOLUNTARY**
Please note that your participation in this study is completely voluntary. Your decision to opt in or out of this study does not affect your status in the IMPACT program or your status at your school site.

**POTENTIAL RISKS AND DISCOMFORTS**
There are no anticipated risks or discomforts associated with your participation in this study.

**POTENTIAL BENEFITS TO SUBJECTS AND/OR SOCIETY**
The results of the research may contribute to improving the teacher education at your district, as well as in your state, and potentially, in the nation. I will be sharing findings with LAUSD and the UCLA IMPACT program in order to help shape future professional develop opportunities to science teachers.

**PAYMENT FOR PARTICIPATION**
You will receive no payment for participation.

**CONFIDENTIALITY**
Your name will be replaced in our research records by a number code. We will destroy all individually identifiable data after data has been coded. Only the research team will have access to the data, and they will be kept locked and secured in our facilities until the end of the study, and then destroyed. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law.

**PARTICIPATION AND WITHDRAWAL**
Participation in this study is entirely voluntary. You may withdraw your consent at any time and
discontinue participation without consequences of any kind. You are not waiving any legal claims, rights or remedies because of your participation in this research study.

IDENTIFICATION OF INVESTIGATOR
If you have questions about this study you may contact the investigator at any time, Lynn Kim-John, at (310) 825-1109 or lkim@gseis.ucla.edu. You may also contact the faculty sponsor with any questions or suggestions, William Sandoval, Ph.D., (310) 794-5431 or sandoval@gseis.ucla.edu.

If you have questions about your rights while taking part in this study, or you have concerns or suggestions and you want to talk to someone other than the researchers about the study, please call the OHRPP at (310) 825-7122 or write to: UCLA Office of the Human Research Protection Program, 11000 Kinross Avenue, Suite 211, Box 951694, Los Angeles, CA 90095-1694.

SIGNATURE OF RESEARCH SUBJECT
I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

________________________________________
Name of Subject

________________________________________
Signature of Subject or Legal Representative Date

SIGNATURE OF INVESTIGATOR
In my judgment the subject is voluntarily and knowingly giving informed consent and possesses the legal capacity to give informed consent to participate in this research study.

________________________________________
Signature of Investigator Date
REFERENCES


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Xiufeng, L. (2006). Effects of combined hands-on laboratory and computer modeling on student
