Chemistry Teachers' Journey through Modeling Instruction:

From Workshop to Classroom

By

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I dedicate this work to my grandmothers, Laura (Cote) Durovec and Ester (Berg) Washburn, for loving me and supporting my education unconditionally. I am eternally grateful for a large family that has always believed more in my ability to achieve than I ever could. For my daily rocks Brent, Jamie, Charlie, and Angelica, I am so thankful for your adaptability and communication – our hard work got me here! I cannot wait to see where our tomorrows will find us.

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ABSTRACT

This presentation will feature case study research that describes the difficulties that four high school chemistry teachers faced while implementing Modeling Instruction into their classrooms. Modeling Instruction is characterized by the development of understanding through cooperative inquiry and collective discourse on a path from concrete to abstract. The complications in transforming a classroom from traditional teacher centered methods to one which focuses on the use of student-centered Modeling Instruction will be thoroughly investigated through the stories of each of the participants. The study begins with observations of the teachers prior to the introduction of Modeling Instruction and follows them into the professional development in the summer, the initial use in the fall term, a follow-up workshop, and finally back into the classrooms. The enlightening findings highlight the difficulties teachers had in aligning the standards, and developing a scope and sequence, as well as reconciling their beliefs about student ability.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE: INTRODUCTION

Students in the United States continue to lag behind other nations in science achievement. The 2007 Trends in International Mathematics and Science Study (TIMSS) found that the average science scores for U.S. fourth graders were below those of four other nations of Singapore, Chinese Taipei, Hong Kong SAR, and Japan. The deficit in science achievement was even more severe when cohort comparisons were made from the 2003 fourth graders to the 2007 eighth graders. The U.S. difference scores proved smaller than those of eight other nations; the four mentioned previously were joined by England, Hungary, Slovenia, and the Russian Federation (Martin et al., 2008). Furthermore, there has been no measurable change in U.S. science scores since 1995 (Gonzales *et al.,* 2008).

Similar disappointing results can be found in the 2009 Program for International Student Assessment (PISA). These results revealed that U.S. 15 year-olds' proficiency levels in science are "average" when compared to all participating countries. Table 1 shows the country rankings specifically as related to the U.S. standings. Of particular importance is that very few students scored at proficiency level six, while a significant number of students scored at a proficiency level of 1 or below (OECD, 2010). At a time when every citizen needs some level of knowledge in science, technology, engineering, and mathematics (NSF, 2008), the need to improve student achievement in science continues to be of paramount importance. Experts in the fields of science education continue to design research based instructional strategies that improve students' achievement; however, as demonstrated the achievement remains fairly static.

Table 1. PISA results highlighting U.S. performance (OECD, 2010)

Science literacy scale	
Country	**Score**
OECD average	501
OECD countries	
Finland	554
Japan	539
Korea, Republic of	538
New Zealand	532
Canada	529
Estonia	528
Australia	527
Netherlands	522
Germany	520
Switzerland	517
United Kingdom	514
Slovenia	512
Poland	508
Ireland	508
Belgium	507
Hungary	503
United States	**502**
Czech Republic	500
Norway	500
Denmark	499
France	498
Iceland	496
Sweden	495
Austria	494
Portugal	493
Slovak Republic	490
Italy	489
Spain	488
Luxembourg	484
Greece	470
Israel	455
Turkey	454
Chile	447
Mexico	416

Science literacy scale	
Country	**Score**
Non-OECD countries	
Shanghai-China	575
Hong Kong-China	549
Singapore	542
Chinese Taipei	520
Liechtenstein	520
Macao-China	511
Latvia	494
Lithuania	491
Croatia	486
Russian Federation	478
Dubai-UAE	466
Serbia, Republic of	443
Bulgaria	439
Romania	428
Uruguay	427
Thailand	425
Jordan	415
Trinidad and Tobago	410
Brazil	405
Colombia	402
Montenegro, Republic of	401
Argentina	401
Tunisia	401
Kazakhstan	400
Albania	391
Indonesia	383
Qatar	379
Panama	376
Azerbaijan	373
Peru	369
Kyrgyz Republic	330

■ Average is higher than the U.S. average
□ Average is not measurably different from the U.S. average
■ Average is lower than the U.S. average

NOTE: The Organization for Economic Cooperation and Development (OECD) average is the average of the national averages of the OECD member countries, with each country weighted equally. Because the Program for International Student Assessment (PISA) is principally an OECD study, the results for non-OECD countries are displayed separately from those of the OECD countries and are not included in the OECD average. Countries are ordered on the basis of average scores, from highest to lowest within the OECD countries and non-OECD countries. Scores are reported on a scale from 0 to 1,000. Score differences as noted between the United States and other countries (as well as between the United States and the OECD average) are significantly different at the .05 level of statistical significance. The standard errors of the estimates are shown in table S1 available at http://nces.ed.gov/surveys/pisa/pisa2009tablefigureexhibit.asp. Italics indicate non-national entities. UAE refers to the United Arab Emirates.

"The most direct route to improving mathematics and science achievement for all students is better mathematics and science teaching" (National Commission on Mathematics and Science Teaching for the 21st Century, 2000, p. 7). The impact of teachers on student learning has been clearly demonstrated (Marzano, 2003; Wright, Horn, & Sanders, 1997). A highly effective teacher can result in student gains of a full two months ahead of the students of an average teacher (Sanders & Rivers, 1996). In contrast, an ineffective teacher can result in students gaining little more than that which would have resulted from a year of maturation (Marzono, 2003). In a longitudinal study that included achievement scores as well as teacher effectiveness scores it was found that low achieving students were more likely to be placed with ineffective teachers. The effective teachers were found to have a firm command of their content, the ability to cover the entire curriculum including complex skills, engage students in learning, while maintaining continual assessment of student learning. The research showed that the effect on learning is compounded by consecutive years of being with an effective or ineffective teacher increasing the gap between high performing and low performing students (Bembry, Jordan, Gomez, Anderson, & Mendro, 1998). These findings indicate that there is a strong need to aid all chemistry teachers in becoming effective.

The development of effective and efficient curriculum designed and tested by educational researchers can assist chemistry teachers. Modeling Instruction is a research-based curriculum that supports high school students' engagement in the processes and discourse of science (Jackson, Dukerich, & Hestenes, 2008). Modeling Instruction will be defined in much more detail later, but for now the chemistry curriculum for Modeling Instruction allows students to construct models of concepts such as pressure. The model is constructed after students have made observations in the laboratory and can provide evidence to support the development. When implemented with high fidelity, the students of teachers utilizing the Modeling Instruction curriculum have demonstrated significant gains in achievement (Hestenes, 2000). The way in which researchers disseminate Modeling Instruction curriculum to teachers is very important. Through the Modeling Instruction professional development, teachers have an opportunity to participate in the roles of student and teacher as designed in the Modeling Instruction curriculum. In doing so, these teachers not only strengthen their own understanding of the content but also their understanding of the pedagogy associated with modeling (Jackson *et al.,* 2008).

Due to the fact that professional development is the means for supporting the cultivation of effective science teachers and in turn improving student achievement in science (Blank, de las Alas, & Smith, 2008) it is important that Modeling Instructional professional development follow the guidelines set forth by previous educational research. In their discussion, Blank *et al.* described key characteristics of effective professional development for science teachers, which included both a focus on content and teacher engagement in learner-centered pedagogies. Many other studies have evaluated professional development to define effective elements. Noting that even with a professional development opportunity which is designed correctly for success the desired instructional strategies are not always implemented into the classroom (Desimone, Porter, Garet, Yoon, & Birman, 2002) . Because of the difficulties encountered changing educational practices using professional development as a medium to the classroom, the ability for the research based curriculum to impact the effectiveness of chemistry education is limited.

Purpose

In the final report of the NSF- Modeling Workshop Project, Modeling Instruction in High School Physics, Hestenes (Principal Investigator) reported on the success of the project, including the increase in both teachers' content knowledge and student achievement (Hestenes, 2000). Within this report, however, he noted that differences in students' performance on the Force Concept Inventory could only be explained by the fidelity of implementation of Modeling Instruction. A key element in the teacher's ability to implement with high fidelity was stated as being their ability to facilitate classroom discourse. With this in mind, the purpose of this research was to examine the impact of Modeling Instruction professional development on instructional practices specifically with chemistry teachers as very little research has been published in this area. To this end, the following research questions were posed:

1. How well do chemistry teachers implement Modeling Instruction in chemistry classrooms, after attending a two week summer workshop?
2. What factors do teachers think impact their ability to implement Modeling Instruction?

3. Does a follow up workshop focusing on discourse have an impact on teacher implementation?
4. What further support could be given to alleviate impediments to implementation?

Significance

The difficulty with impacting teacher practices can be addressed by studying the implementation. This study will add knowledge that assist in building a better understanding of how to move research based curriculum from the conferences to the classroom. Currently the best practices have not been explored in depth. Particularly in regards to teachers barriers to implementation. This study will help to identify areas in which teachers need further support; giving researchers the opportunity to design programs which facilitate teacher engagement with research based instructional techniques.

CHAPTER TWO: LITERATURE REVIEW

A brief history and overview of Modeling Instruction follows, it provides a foundation of understanding about the bases for the research being conducted as it pertains to science education. The Modeling Instruction curriculum presented to the teachers during a professional development requires that previous research findings highlighting the benefits and characteristics of effective professional development experiences are also discussed. The effective practices of professional developments will be examined as related to instructional changes that occur in teachers' classroom practice.

Modeling Instruction

Modeling Instruction is a research-based instructional method developed for high school science educational reform (Dukerich & Jackson, 2012). This program began at Arizona State University (ASU) specifically as a model-centered approach to an alternative to traditional physics instruction which employed the concept of learning cycles (Wells, Hestenes, & Swackhamer, 1995). Learning cycles consist of student exploration, concept development, and application. Jackson and colleagues (2008) summarized the Modeling cycle which consists of two stages. The first stage of model development begins with a lab investigation or demonstration. It is followed by small group collaboration after which the group findings are presented to the whole class for clarification and justification. In order to develop an overarching model an analysis of all the results is conducted through student discourse. The next stage, model deployment, gives students the opportunity to apply their understanding to new problems and situations. The model is then used to examine real world phenomenon, and just like most scientific models, at some point the model will fail. The failure of one model will restart the cycle. Modeling Instruction is characterized by the development of understanding through cooperative inquiry and collective discourse on a path from concrete to abstract (Wells *et al.*, 1995).

Research over the past 20 years has continued to demonstrate the effectiveness of modeling instruction on improving student understanding of physic concepts as measured by the Force Concept Inventory (FCI) (Savinainen & Viiri, 2008). After one year of education under instructors deemed novice modelers, students increased their FCI scores an average of 27%, while students under expert modelers, increased an average of 43% (Hestenes, 2000). Malone (2008) reported that modeling students developed more "expert-like problem-solving skills," leading to less mistakes and better understanding which translated into better achievement in physics. Similarly, researchers at Florida International University implemented modeling-type reform lab sections along with traditional labs sections in their introductory physics classes, and found students in the reform labs increased their FCI scores more than those in the traditional labs (Brewe *et al.*, 2010). Additionally, modeling instruction has been shown to provide benefits other than purely academic gains such as increasing positive attitudes toward physics (Brewe *et al.*, 2008) and facilitating the development of more student-to-student interaction while developing a sense of community within the classroom (Brewe *et al.*, 2010). The positive attitude shift is clearly demonstrated with results from the Colorado Learning Attitudes about Science Survey (CLASS) seen in Figure 1. The triumph of Modeling Instruction in physics has become well known for the successful dissemination of practice through professional development (Lee *et al.*, 2012). Physics education where Modeling Instruction was first designed and implemented has been well documented. The success of the physics Modeling Instruction curriculum prompted the design of a modeling curriculum for chemistry instruction. The full curriculum was first piloted at ASU in 2005. The research in this study will help to document the impact of Modeling Instruction professional development on chemistry teacher's practices.

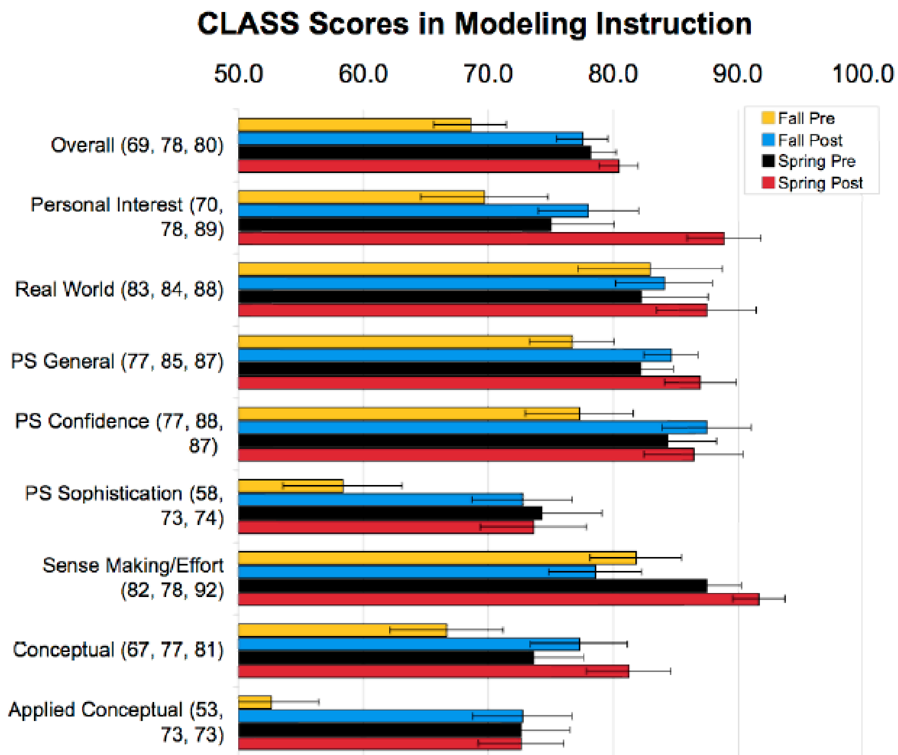

Figure 1. CLASS scores in each semester of study involving students enrolled in an university physics course (Brewe et al., 2008).

Professional Development

The importance of professional development is highlighted with the knowledge that teachers play a critical role in the potential for student learning (Ding & Sherman, 2006). Although not every professional development has been successful, strides have been taken by researchers to improve teacher engagement by determining that professional development was shown to be an effective way of reaching teachers with the most current practices for instruction (Lumpe, Czerniak, & Haney, 2012), with the potential ability to change their instructional practices (Desimone et al., 2002). Extensive research in this area has identified key components of effective professional development activities (Garet, Porter, Desimone, Birman, & Yoon, 2001). The components of professional development that are most highlighted are those that correlate significantly to student achievement as seen in Figure 2. The education of teachers through an informative professional development activity comprising effective research-based components is a proven way to impact student learning (Lumpe et al., 2012). The research based components will be examined in more detail and include characteristics such as a focus on content and how students learn the content.

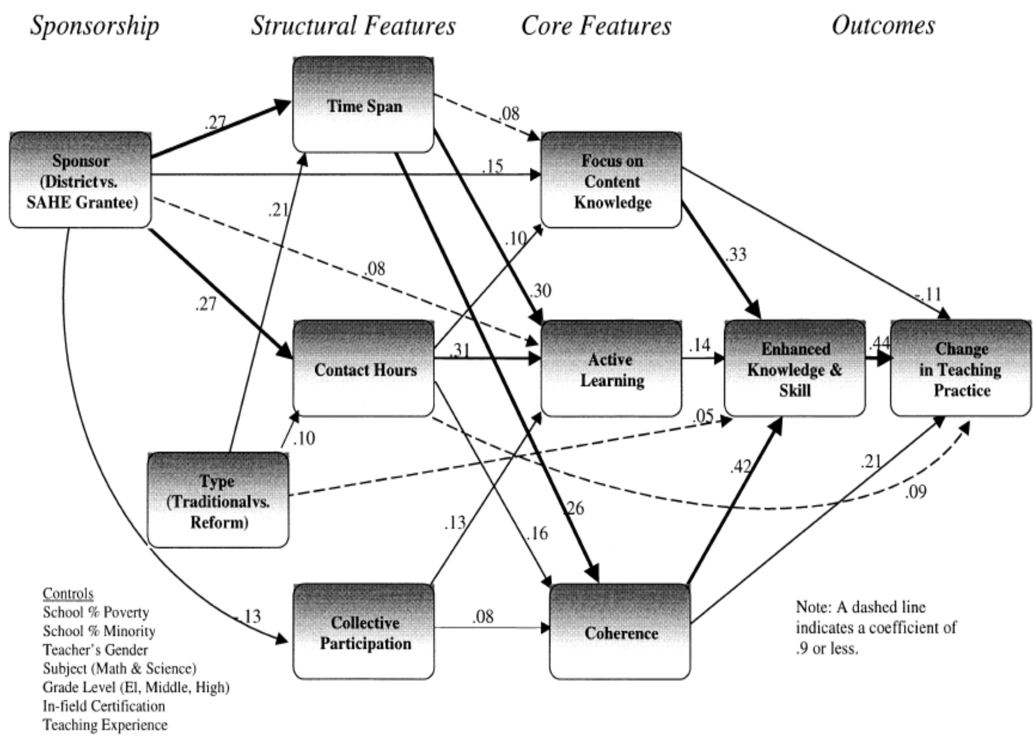

Figure 2. Relationships between professional development and teaching reforms (Garet et al., 2001)

Professional development is an effective tool for improving teacher's knowledge as well as instructional practices (Desimone et al., 2002; Donnelly & Argyle, 2011). In a longitudinal study by Desimone and colleagues (2002), teacher practice and learning from a variety of professional development experiences were examined to determine effective components. The research was conducted as part of the larger Eisenhower Professional Development program – Title II of the Elementary and Secondary Education

Act. The sample size of the study was 207 teachers from 30 schools in five states comprised of 10 districts. The selections included elementary, middle, and high schools in a variety of socioeconomic conditions. Surveys were used to determine how teaching practice changed between year one and year three. The surveys requested information from teachers pertaining to the structure of their professional development including reform type, duration and if the activity emphasized collective participation from other teachers of the same subject, school, or grade level. Other features pertained to the substance of the reform, such as active learning opportunities, coherence of professional development, and the content focus. The variance in teaching practice was contributed to the professional development that teachers participated in during year two, with year one being the baseline. They found that teachers who participated in professional development instruction with specific teaching practices significantly increased the use of those practices in their classrooms. The connections found during the research between the structural and core features of a professional development and outcomes, along with the strength of each correlation are shown in Figure 2 (Garet et al., 2001). Another increase was seen with technology utilization in the classrooms when it was part of the professional development experience (Desimone et al., 2002).

It has been clearly demonstrated that quality professional development benefits teachers and their students; however, not all professional development has been found to be effective. Desimone (2009) synthesized key components of professional development to construct a conceptual framework and core features which previous research had shown to positively impact teacher beliefs and practices, and in turn improved student achievement. She posed the following question. "How can we best measure professional development, and its effects on teachers and students, toward the end of improving professional development programs and policies to foster better instruction and student achievement?" (Desimone, 2009) The framework she provided was designed to assist future researchers. The framework gave a platform with which to examine data collected in regards to professional development. The five components she found that supported teacher implementation were content focus, active learning, coherence, duration, and collective participation.

First, Desimone recognized effective professional development should be content-focused. Highlighting content-based activities including how students learn the material increased teachers' own content knowledge as well as their pedagogical content knowledge as defined by Shulman (1986). Professional developments that provided focus on content have been demonstrated to produce positive changes in teacher instructional practices and to a slight degree student achievement (Desimone, 2009). Another key feature of quality professional development according to Desimone was the opportunity for teachers to engage in active learning. Active learning involves activities such as observing experts and being observed, receiving feedback, participating in and leading discussions and evaluating student work. For professional development to be most effective, it must be of a sufficient duration. Although research has not identified a specific length of time, research has demonstrated that to be effective, professional development should consist of a minimum of 20 contact hours over a span of at least a semester.

The reaming core features Desimone identified included aspects of teachers' environment. Such as coherence, which relates to the state and district policy and individual teacher beliefs aligning with the desired instructional expectations set forth during a professional development. Finally effective professional development exhibited the feature of collective participation. Collective participation refers to teachers in the same grade, department, or school. The core features were accompanied by a theoretical framework which emphasized the need to be explicit when examining the links between the five core features of the professional development, teacher practice, and student achievement.

In a study that focused on one experience Donnelly and Argyle (2011) demonstrated that a professional development graduate course designed to improve teaching and learning of basic physics resulted in teachers increasing their implementation of activities presented in the course in their classrooms. The course met on eight Saturdays during the school year. The activities were designed to promote a better understanding of the Nature of Science (NOS). The aspects of NOS that were targeted in this study included the concept that scientific knowledge is tentative, but durable. Scientific knowledge is partly based on human imagination and creativity, although empirically based scientific knowledge is theory-laden and subjective. Scientists make observations and inferences to generate scientific knowledge. Another important aspect of NOS is the difference between laws which describe patterns or regularities in data, and theories which are explanations of the data.

The importance of NOS in science education prompted the researchers to evaluate the 36 participants of this course that included science teachers from elementary, middle and high schools. Data collected included the use of Views of Nature of Science (VNOS-B) questionnaire which had previously been developed and validated for use with high school, preservice, and in-service teachers (Lederman et al. 2002), exit slips from each class in the professional development, journal reflections from teachers, and a survey after course completion. The survey requested information about the use of NOS activities in teacher classrooms before and after the professional development. The data from the questionnaires was entered into a spreadsheet for independent coding by researchers this was the quantitative piece of the study. The final survey which asked for data about how NOS practices had changed and were now used in teachers classrooms, was completed and returned by 11 participants.

Teachers were found to have begun with adequate knowledge in all of the NOS views that were highlighted in the course. The NOS views for teachers were improved from pre to post questionnaires although only two gains were statistically significant. The improvements were seen in theory/law distinctions and the role of indirect evidence in science. Further statistical analysis was done when ANOVA was used for the analysis of survey data.   The survey revealed that an average of three NOS activities were implemented in teachers' classes during the course, three teachers reported not using any of the activities.

One difference was found when school demographics were examined that was a lower average of NOS activities in urban schools 2.2 compared to suburban 3.6. Several assertions were made in the examination of qualitative data. Some teachers initially found the NOS instruction to be a waste of time, although they were especially open to the theory-law activity. Teachers ended the course with an appreciation of the NOS activities found in the course. Ultimately the instructional practices the professional development focused on were put into practice by most of the teachers, Table 2 shows how many teachers reported implementing each activity (Donnelly & Argyle, 2011).

Table 2. NOS activities implemented by teachers (Donnelly & Argyle, 2011)

NOS activity	Number of teachers who used
Mystery tube	24
Tricky track	19
Cubes	19
Mystery circuit boards	12
Mystery magnet box	12
Mystery water maker	11
NOS PowerPoint	8
Hole picture	6
Theory law activity	6

Importantly, the impact that the professional development had on teachers was not only on their practices in the classroom, but on their content knowledge base as well.

While the impact of professional development on teacher content knowledge and instructional practice is profound in some examples, impact is also apparent on teachers' self-efficacy and beliefs about their teaching effectiveness. Lumpe, Czerniak, Haney, and Beltyukova (2012) studied the effects of a large scale professional development program designed to make a comprehensive change in science education for elementary schools, kindergarten through six. Teachers participated in the research based professional development for two weeks during the summer and met with a support teacher throughout the school year biweekly. The professional development included science content knowledge, inquiry based instruction, and scientific processes relating to the district standards. More than 400 elementary school science teachers participated in this professional development, which included 16 teachers that were relieved from instruction to provide assistance with implementation. "Support teachers received more than 200 contact hours of leadership training in the form of a 2-week summer program, two graduate courses, a staff retreat, and a spring conference" (Lumpe et al., 2012).

Other important members of the educational community were also involved in this system wide change. All of the principals from the district attended a one day retreat which informed them of the science education reform research. The support teachers were also involved in providing two community meetings which were designed to involve parents and other professionals in the district. The professional development was designed to include the core features as defined by Desimone (2009).

The teachers took a statistically validated survey before and after to identify any changes in their self-efficacy beliefs. The results revealed a significant increase to teacher science teaching self-efficacy beliefs. It was also shown that teachers' beliefs and the number of hours they participated in the professional development were both positive predictors of student achievement. This study demonstrated that effecting positive changes in teachers through professional development leads to positive benefits for their students' achievement.

Modeling Instruction professional development incorporates many of these components of quality teacher training. The Modeling Instruction professional development is focused on enhancing teachers' scientific content knowledge while allowing them to experience the Modeling Instruction method. Additionally, the professional development provides active learning opportunities and duration of 88 contact hours. In this way we would expect to have a positive impact on teacher classroom practices.

Fidelity of Implementation

Professional development has an impact on teacher instructional practices, which in turn leads to improvements in student achievement, at least some of the time (Schroeder *et al.* , 2007). Teachers' that all attend the same professional development have been found to have student learning gains that vary widely, with not all gains being positive (Hestenes, 2000; Penuel & Means, 2004). One consistent hypothesis offered by researchers to account for these differences is that some of the teachers are not following the design of the instructional practices established during the professional development, i.e. low implementation fidelity. The term implementation fidelity has been widely defined as how well a new program implemented by practitioners aligns with how it was originally intended by the developers (Carroll *et al.*, 2007; O'Donnell, 2008). The hypothesis regarding fidelity of implementation was supported with research conducted by Taylor, Scotter and Coulson (2007) who reported a strong relationship between high implementation fidelity and student learning gains in biology, related to the implementation of the Biological Science Curriculum 5E Instructional Model (BSCS 5E).

High fidelity of implementation of an effective professional development program resulted in greater increases in student achievement when compared to that of low implementation fidelity (Penuel & Means, 2004; Stein et al., 2008). The work conducted by Penuel and Means (2004) investigated the GLOBE program which is a science inquiry initiative for grade K-12. The GLOBE program collects information from activities teachers conduct with their students monitoring rivers. The data collection method allowed researchers to obtain implementation fidelity information from a web-archive. Teachers varied in reason for not implementing; importantly teachers that did not understand the relationship to student learning goals and the curriculum were less likely to successfully implement the curriculum. Similarly, Hestenes (2000) demonstrated the implications of high implementation fidelity in Modeling Instruction. He specifically showed that students of teachers with a high fidelity of implementation of Modeling Instruction practices had higher achievement gains than those of teachers with a low fidelity of implementation.

Identifying the factors that influence a teachers' ability to more effectively apply important ideas and skills from the professional development to their classrooms can provide insight into how to increase the fidelity of implementation of Modeling Instruction. Spillane, Reiser, and Reimer (2002) highlighted the importance of "sense-making" for teachers to be able to implement with integrity. They posited that the teachers' knowledge, beliefs and attitudes interact with the situation and the policy itself to influence how effectively they understand the new policy, thus impacting their fidelity of implementation. Inability to implement with integrity is often not due to outright rejection of the ideas, but merely a result of misunderstanding or the teacher's cognitive construction of ideas that do not perfectly align with the policy's intent. This is more likely to occur when the teachers' existing knowledge structures and cognitive patterns are significantly different from those required of the reform program. Additionally, the authors suggested that implementation fidelity suffers when the practitioners perceive the new program as contrary to their goals, interests, or prior agendas (Spillane et al., 2002)

There are also specific characteristics of program design and dissemination that can impact teachers' fidelity of implementation. One study about implementing a new reading program with kindergarten teachers revealed the benefits of providing highly structured plans for the teachers, and having an extra follow-up workshop (Stein *et al.,* 2008). In a review of research, O'Donnell (2008) found that there was better fidelity of implementation when the program was explained with "clarity and specificity" rather than in more general terms. In a qualitative study specifically about Modeling Instruction, researchers identified key influences that affected teachers' ability to effectively implement and disseminate the method (Lee et al., 2012). They found it was important to provide teachers with the physical space and resources required for the innovation, as well as supporting their empowerment through a sense of ownership. In Modeling Instruction this is done by encouraging teachers' to add to and adapt the curriculum while developing and participating in a supportive community (Lee et al., 2012).

Professional development can be used to impact many areas of instruction all around the world; however, fidelity of implementation varies even with the use of successful strategies. In the following study which took place in Swaziland, Stronkhorst and Akker (2006) analyzed science teachers as they participated in an in-service which supported student-centered teaching. The promotion of student-centered approaches was successful in teachers that had more experience although this trend was not seen in less experienced teachers. The results highlighted behaviors of teachers based on the characteristics that were observed. The teacher metaphors developed as a result of this study will provide a framework in which to relate teachers that participate in the Modeling Instruction professional development.

The analysis of all the data collected revealed that the teachers in the study could be summarized with several distinct teacher metaphors. The first was that of the "inexperienced survivor" - these teachers had initial observed difficulties in managing class rooms as well as workload. For this reason, improvement was seen in the intended direction for basic teaching skills implemented. These teachers, however, did not move towards student-centered curriculum. The task was thought to be simply too demanding. "Experienced Talker and Chalker" these teachers stuck to their teacher centered style. The researchers found that asking these teachers to change without support from the specific system they operated in was futile. "Pragmatic adjuster" changed very little in regards to basic skills, but adopted a slightly more student-centered approach. These teachers were willing to slightly adjust their teaching style where they saw it as necessary, or plausible. "Revolutionary Charger” this teacher moved towards the implementation of both basic skills as well as a more student-centered approach. The changes were radical making the adjustment difficult for both teacher and students (Stronkhorst & Akker, 2006). The four metaphors Inexperienced Survivor, Experienced Talker and Chalker, Pragmatic Adjuster, and Revolutionary Charger provide broad categories that encompass teacher practices that may be applicable to discussion.

CHAPTER THREE: METHODOLOGY

This qualitative study of chemistry teachers' implementation of Modeling Instruction uses a combination of classroom observation and interview data. Due to the importance of understanding implementation as it pertains to chemistry Modeling Instruction, an in-depth examination of four high school chemistry teacher's journey through this implementation will be conducted. The teachers selected as participants for the case studies were chosen based on their proximity to the researcher, and their field of study, from a larger group of participants in the Modeling professional development. The participants were part of a two week long professional development on the Modeling Instruction curriculum for high school science teachers, carried out in the summer of 2012, with a follow-up Saturday workshop in October.

The professional development was part of a grant from the Math Science Partnership program through the Tennessee Higher Education Commission. The grant supported the professional development of science teachers within the state of Tennessee. The participants were provided with room and board, college credit, and financial compensation for their time at the workshop. The case study participants were selected from one district primarily due to the convenience of travel to each of the schools to make observations and conduct interviews. The four participants were purposefully selected from the available chemistry teachers that had participated in the workshop. Individual participants were chosen from the same district, assuring that participant teachers' would be following similar standards, and consistency in employer expectations. To obtain breadth of in data collection, a variety of other considerations were taken into account for sample diversity including: gender, years teaching, education level, and school were currently teaching.

In, spring 2012, a semester prior to the professional development workshop, baseline observations were conducted by the researchers. The study participants were observed on a date that was agreed upon in advance by the participants and researchers. The protocols for observation were developed after careful consideration of the professional development content. The Reform Teaching Observation Protocol (RTOP), a tool specifically designed to evaluate the use of constructivist instruction in mathematics and science classrooms (Sawada & Piburn, 2000), was used to document classroom observations. The specificity of curriculum used by the study participants made it necessary for additional notes to be taken by the investigators. Case-study research uses observational guides and procedures that are very specific and constructed for settings were the participants feel most at ease (Algozzine & Hancock, 2006). Therefore an additional observation check list (Appendix A) was designed by the investigator to identify characteristics that were indicators of Modeling Instruction occurring in the classrooms. The list consisted of 11 yes or no questions with an area left for further explanation if the observer felt it was necessary. The questions focused on the aspects of data reporting which included student presentation and the use of white boards in collaboration. Two researchers trained in the use of the RTOP made the observations in the classrooms together – scoring them independently. Following each observation, the researchers took time to evaluate the experience and record additional field notes increasing the richness of the data collected. Upon completion of individual observations the researchers came together to agree on a combined rank for each RTOP item. Observations for each classroom visit were conducted using the same procedure.

In addition to classroom observations, the researcher was a participant observer in the two-week professional development workshop conducted in the summer of 2012 and collected field notes throughout this experience as well. Creswell (2013) explains that participation allows the researcher to gain an insider's perspective; however, given the integration into the professional development there is an increased potential for distraction. In order to provide additional resources to ensure the fidelity of data the professional development classroom was video recorded. The participant observer technique originally used in ethnographic studies to understand a culture (Creswell, 2013), allowed the researcher to interact with the teachers in a different way; providing access to their thinking from a more collegial perspective.

Interviews as a data collection technique are particularly useful in case studies. The small number of participants allow for a rich understanding of practice (Mason, 2002). In this study individual interviews were used because of their ability to provide personal insights from each of the participants. A semi-structured interview technique was used in which the same open-ended questions are asked of each participant with follow-up questions that allow for further elaboration or specific ideas within an interview (Algozzine & Hancock, 2006). Interview protocols were established in advance of each meeting post professional development (Appendix B).

The first observations and interviews after the professional development took place with in the month of September where data collected informed the construction of a one day follow-up workshop carried out in October. The main concerns stated by the participants in terms of successful implementation of Modeling Instruction were addressed in the Fall follow-up workshop. Unfortunately none of the participants of the case study were able to attend the full day follow-up workshop designed to assist in the implementation. In order to procure some follow-up for the research participants, another one hour workshop was designed specifically focused on discourse. Discourse was chosen as the topic for the workshop for two main reasons. The first is that Hesteneses, the initial designer of Modeling Instruction professional development, reported discourse as being one of the main reasons for lack of curriculum implementation (Hestenes, 2000). The second reason was that participants indicated students had a difficult time communicating their ideas to one another. This issue of facilitating discussion seemed to be key to success in implementing Modeling Instruction, therefore a good topic for a short focused workshop The discourse workshop was opened up to all science teachers that had participated in the grant. The additional seminar was offered twice as a way to encourage all research participants to attend. After the completion of the follow-up discourse workshop the teachers were observed and interviewed for the final time in November.

Instrumentation

RTOP.

The reformed teaching observation protocol (RTOP) was developed to monitor reformed teaching practices in the classroom (Sawada & Piburn, 2000). Originally designed to assist in teacher preparation, the validity and reliability of the instrument in science classrooms has been well documented (Marshall, Smart, Lotter, and Sibu, 2011). The researchers conducting observations were trained to correctly score instructional practices. The RTOP form that was utilized includes areas for classroom descriptions, teacher background information, and places for detailed field notes. The instrument itself consist of 25 statements which were rated on a scale from zero (never occurred) to four (very descriptive). The designers of the instrument provided complete descriptions on how to interpret each statement within the context of reformed teaching. Previous research has identified three factors that characterize the instrument: inquiry orientation, content propositional knowledge, and collaboration (Sawada & Piburn, 2000). The design of Modeling Instruction is based on the same foundation as other reform curriculum with a strong constructivist approach to learning focusing on similar classroom behaviors (Wells *et al.*, 1995).

Teacher behaviors were rated in three categories important to reformed teaching as well as Modeling Instruction. The category of lesson design and implementation contained statements that demonstrated the teachers’ ability to be flexible based on student understanding. In a reformed classroom, teachers’ behaviors were described as being encouraging to students' divergent patterns of thinking; instruction focused on a collective exploration of problem solving to socially construct knowledge (Sawada & Piburn, 2000). Content subdivided into categories of propositional and procedural knowledge. Propositional knowledge behaviors demonstrated understanding and conceptual connectivity of subject matter to real world. Alternately, procedural knowledge behaviors focused on the students' interactions with the subject matter. Scientific reasoning was evident in the classroom, because students' were engaged in their understanding of content. The final category, classroom culture, focused on the relationships in the classroom. Reformed classrooms encouraged respectful and complex communication between students, as well as between teacher and student. RTOP themes allowed for a more precise understanding of teachers instructional changes that were correlated with the professional development.

Researcher.

In accordance with a pragmatic framework, every attempt was made to observe the classrooms in an unbiased way. Pragmatism axiological beliefs maintained that knowledge constructed by researchers' included the values held by the researcher (Creswell, 2013). The reported information was processed, reported, and observed by an individual; as such, the researcher biases and personal experience that potentially do influenced data analysis and interpretation have been disclosed.

The researcher was a non-traditional student throughout her college career. A chemistry education major was decided during the first year of classes, which were completed at a community college while earning an AS degree. Instructors at the community college worked very hard to implement current research in chemistry education into their practices. While earning a Bachelor's degree in chemistry the instructional techniques professors in chemistry content courses used included strategies from problem based learning, collaborative learning, process oriented guided inquiry learning, and integrated technology into the classrooms. Teacher preparation, with a fifth through twelfth grade licensure included education classes with a focus on how students learn, and the difference environmental factors can make on students. Requirements for completion of a BA in chemistry included an undergraduate thesis on interest and attitudes in chemistry as impacted by instructional practices which initiated chemical education research. Upper division chemistry education courses were completed while working as a learning assistant for quantitative analytical chemistry as an undergraduate.

CHAPTER FOUR: RESULTS

RTOP Scores

Total RTOP scores for each participating teacher were reported in Table 3. The norm score in high school science classrooms given for comparison were a mean of 41.8 and *SD* 20.2 (Sawada & Piburn, 2000), in baseline observations two teachers, North and South were within the range of average teacher scores. After the summer intensive workshop one teacher, North, had an above average score while each of the remaining three were on the border between below and average scores. The final observations, taken after a workshop related to facilitating classroom discourse, indicated that two teachers were within the average range, North and West.

Table 3.

RTOP Scores Before and After Each Professional Development

Teacher	April	September	November
North	52	85	56
West	6	21	12
South	30	21	20
East	14	21	25

Each teacher in the study with the exception of South demonstrated growth after the summer professional development. The final observations taken after the workshop showed a decrease in teacher scores with the exception of West which had a slight increase. South was the only teacher that did not increase their total RTOP score from baseline to final observation.

Professional Development

The Modeling Instruction professional development (PD) was a two week long workshop. The workshop was conducted in a high school chemistry classroom. The PD provided teachers with an overview of the lessons necessary to implement high school chemistry one. The content was delivered in an active environment in which the participants, taking on the role of students, worked collaboratively to explore the curriculum as presented by Modeling Instructor leaders. The two leaders that taught the PD were practicing teachers that used Modeling Instruction in their chemistry classrooms. One of the leaders taught in public schools while the other was a private school teacher. The focus of the workshop was on the presentation of chemistry content through student exploration and discussion.

The workshop started with a schedule of events and a brief overview of the curriculum needed for instruction. Each participant was given a laboratory notebook, composition notebook with graph paper, and a binder of curriculum material. The curriculum material was presented in a large binder separated out in units one through nine. Modeling Instruction was described as a way for students to learn through their own development of a mental model. The onus for learning the material was to be given to the students. As an introduction to each unit students were given a study guide listing their learning objectives. The curriculum was described as being student-centered and involved a lot of classroom conversation with Socratic questioning from the teachers. The leaders emphasized the importance of setting guide lines for having respectful conversations. Teachers were encouraged to have a similar conversation on the first day of Modeling Instruction in their own classroom.

In order to help participants understand the curriculum we were asked to switch between student mode and teacher mode. In student mode we completed assignments in the same manner that our students would later be completing the assignments. In this mode the focus was on content, and understanding the ways in which students would need to interact collaboratively. In student mode it was necessary to think as a student with little or no understanding of chemistry and molecular interactions. In this way participants became aware of the interactions and communication skills that are necessary for participation in a Modeling Instruction learning environment. In teacher mode the participants could ask questions about how to facilitate group discussion, what information to present to students, and voice difficulties they perceived in their own classes. Leaders focused on giving examples from their own experiences teaching with Modeling Instruction. The leaders worked to answer questions and concerns the participants presented as they related to each unit of instruction.

The binder that was given to instructors contained an introductory sheet to Modeling Chemistry, readings for the workshop participants, and step by step guides for each unit. The introduction to Chemistry Modeling describes the development of the particle model for understanding chemistry. The overarching questions that guide the approach are:

1. How do we view matter? (Answer in terms of the particle you are using to describe matter)
2. How does matter behave? (Provide an explanation for behavior using the particle model)
3. What is the role of energy in the changes we observe?

The leaders asked participants to develop a list of key concepts they thought were necessary for students to understand chemistry. Many teachers highlighted the state standards as being important. The facilitators compiled a check list of concepts given by the teachers which included: atoms, molecules, and ions - particulate theory of matter – stoichiometry - chemical reactions and balancing - conceptual energy - mole concept - periodic table trends - lab skills - dimensional analysis - VSPER model - Geometry and polarity – nuclear. Discussion focused on how each of these concepts were explored in the curriculum, with the exception of nuclear chemistry and the VSPER model. Construction of student knowledge was demonstrated by the leaders as they assisted teachers by using clarifying questioning to build understanding.

Several of the big ideas are explored in each of the 9 units. Unit 1 explores the composition of matter in terms of featureless BB's which have mass and volume. Unit 2 explains the random thermal movement that constantly occurs for the particles. Unit 3 develops the idea that particles have attractions to each other. The unit also continues the discussion of energy conservation explaining that it is stored and transferred in several ways. Unit 4 introduces the idea that substances can be made of compounds which have a definite composition. The formulas for compounds are deduced from the evidence found by combining volumes and knowing the masses. Unit 5 continues the discussion of molecules, through the use of Avogadro's hypothesis to determine the number of particles in a macroscopic sample. Unit 6 develops the concept of charge leading to the understanding of molecular versus ionic substances. Unit 7 delves into chemical reactions. The unit focuses not only on the rearrangement of particles, but also on the energy transfers that occurring during this rearrangement. Unit 8 introduces stoichiometry; emphasis is placed on the conceptual realization that the number of particles is related to weighable amounts of these particles. Unit 9 continues the exploration of chemical equations as the numbers of particles are related to volumes in gases and solutions. The unit also expands on the connection between the amount of particles and the change in energy. Every unit, one through nine, found in the binder included a list of instructional goals and notes which provided an overview of the ways the teacher should progress discussion through the unit. The instructional overview contains the order in which teachers should precede through demonstrations, labs, worksheets, videos, readings, quizzes, reviews, and tests. The professional development did not emphasize this overview; instead teachers were guided through the units to experience the curriculum.

Each unit in Modeling Instruction begins with either an experiment or a demonstration. In the PD, unit 1 started with a demonstration of an exploding coffee can. Participants were asked to explain what had occurred at the particulate level during various points in the demonstration. We were separated into groups of four and asked to draw our answers on a white board in a comic strip with beginning middle and end. Upon completion of the task we came together as a large group to discuss our findings. The demonstration was of a combustion reaction –the participants had a difficult time describing the reaction at the particulate level. The leaders used the fact that even teachers were challenged when asked to conceptually explain what has occurred in this complex system to emphasize the importance of breaking down chemistry into smaller parts. In order to facilitate this understanding, teachers were told to work with their students while developing the fundamentals of chemistry. In Modeling Instruction understanding builds from observing teacher demonstrations, collecting background information, participating in laboratory explorations with group discourse, and developing a model to explain the student knowledge structure.

Every unit contains at least one experiment or demonstration. Each lab that occurs during Modeling Instruction requires the students to complete a lab report. The formats for the lab report along with assigned roles were provided prior to the first experiment.

Each laboratory team consisted of three or four individuals. The individuals were assigned roles of lab manager, recorder and technicians. The lab manager was responsible for directing the experiment. The responsibility of directing included, writing the first four sections of the lab report, writing instructions during the prelab briefing, being responsible for the safety of the team during the experiment, and being the primary spokesperson during the board meeting. The lab managers sections of the lab report directly correlated to the responsibilities they had

1. List the members of the team and their roles
2. Explain why the experiment was conducted
3. Sketch the equipment assembly and explain the procedures
4. Safety hazards.

The recorder collected all the data and observations produced during the experiment as well as completing that section of the lab report. The recorder also wrote the data section of the written report, provided team data to compile with class data, and writes on the white board for the board meeting. During the board meeting the reporter holds the team's white board. The technicians were responsible for gathering materials and conducting the experiment. The technicians were the only ones allowed to leave the lab bench with just one being the gopher. They answered questions during the board meeting, and conducted clean-up of all procedures. The two individuals that were technicians during the first lab were the other roles during the next lab. The final two sections of the lab report were the evaluation and conclusion sections these were complete by the entire team.

A notable difference from this learning experience compared to any other class that I have taken or instructed is that the leader at no point indicated that the conclusions were correct. The students are supposed to construct their own understanding of the data. This idea was very difficult for the teachers to accept. Several teachers voiced concerns about not giving the students the “right” answer, particularly because students would be required by standardized tests to have a traditional definition. The instructors emphasized the success they had seen in their students on AP exams and ACT tests. The indication was that student understanding would be deep enough that they would be able to successfully think their way to the correct answer.

A significant amount of time was spent on the first unit. In this way participants became familiar with how students were expected to construct a coherent understanding of concepts. In this unit participants worked through three worksheets, three labs, a review and the test. Through the lab work participants constructed additional models which included volume and density. The worksheets were used to focus in on mathematical relationships between volume and mass as well as demonstrate the differences in particle distribution for various substances. The concepts covered in the first unit included mass, volume, and density, as well as accuracy and precision in data collection.

Teacher Experiences

The interviews for all high school sciences, not just the chemistry participants, were analyzed and evaluated to identify the topics that teachers indicated would be influential. The themes from the first round of interviews were identified as being either internal or external to the participants (Barlow, Frick, Barker, & Phelps, 2014). The interviews for four of the chemistry teachers were subsequently analyzed separately.

The teachers' were assigned the pseudonyms of Ms. North, Mr. South, Ms. East, and Ms. West. Each case study will be presented in the following format: background which provides demographic information pertaining to each of the participants, interview themes, and RTOP analysis. Interview themes that emerged included Adaptation, which involved changing the Modeling Instruction curriculum to involve instructional techniques different from those taught during the professional development. The theme of Facilitation refers to the teachers' descriptions of how teachers promoted student discussion. Pacing was a category that emerged in tandem with Content. To assist in differentiation pacing involved any comments pertaining to any length of time associated with the implementation of Modeling Instruction. In contrast the area of content refers to teachers' statements involving chemistry as the subject matter. Teachers' discussion pertaining to their students included the themes Student Understanding, Student Participation, and Student Ability. The Social theme contained teacher comments regarding either administration or colleagues. The final category Instructional was a theme that emerged in regards to changes teachers' described relating to their instructional practices.

Ms. North.

Background.

Ms. North was a Caucasian woman in her forties. At the time of the study, she taught three sections of chemistry as well as several sections of Principles of Technology. She had taught for thirteen years, and was the only chemistry teacher in her school. She held a Bachelor of Science in biology and education, as well as a master's degree in science education. She also held an Ed.D. in curriculum and instruction.

Ms. North taught chemistry in a rural school in the southeastern United States. The school included grades kindergarten through twelfth. The statistics for the 2012-2013 school year listed the student population at 860 students with 94% of the students as white. The school had a 99% graduation rate with an average ACT score of 19.9. The student population had 31% of students economically disadvantaged and 12% of the students reported having a disability.

Adaptation.

Ms. North's classroom involved students in engaging activities both before and after the professional development. As she stated, "I'm still very much an inquiry-based teacher. You were in my classroom before, I stress the engagement" (Interview, North, 2012, September 26). The initial observations of her classroom confirmed that Ms. North was actively working to reform her classroom to a more student-centered environment. The desire to change curriculum to facilitate student learning was initiated by Ms. North prior to the introduction of Modeling Instruction during the professional development. She was already conducting action research on an innovative approach to laboratory experiments, referred to as science writing heuristic.

> Science writing heuristic is an instructional strategy where students design labs based on their questions. And then they, of course, they have to get those procedures approved. Then they carry out those labs and make claims based on their evidence. Then they compare their evidence, their data, with the class - then look at trends. And then they compare that with the scientific community. And then they, um, reflect on what their hypothesis [is], for that particular question. And then they, we write on what they have learned. So I'm getting ready to do a density lab, going into the density lab using some of the same kinds of things, but a little bit differently. Getting the kids to, leading them to ask well is the density of this the same as this? Or does the volume effect density? Or does mass effect density? (Interview, North, 2012, September 26)

In this quote, Ms. North explained that she had altered the labs designed for the Modeling Instruction curriculum so that science writing heuristics could also be utilized as an instructional technique.

The adaptations that Ms. North made to the Modeling Instruction Curriculum were explained in the following excerpt.

> I'm actually, I'm doing my own research funded by the National Science Foundation employing chemistry Modeling Instruction and science writing heuristic, looking at how that works. How that, can those be blended and that, well this is my fourth cycle of research with science writing heuristic. It's obviously, you know I'm a newbie to Modeling and so I'm learning and finding some very valuable things. (Interview, North, 2012, September 26)

Her initial adaptation was used during the first months of school and included the density lab which was provided in the Modeling materials. She worked to meld both instructional innovations, "in which the students are designing the labs so that's being incorporating with this. So I am sort of blending the two together (Interview, North, 2012, September 26).

She described this blending as follows:

> They came up with … a testable question that relates to some of the things we've talked about. They came up … does mass increase as volume increases? Does density change as mass changes, and does density change as volume changes? Those are the questions I wanted them to come too, so it was guided…they decided which question they wanted … design an experiment where you answer this question and so they did and then they had to get it approved … They had to decide … where are we going to put our data in terms of this table and then we need to graph this data. Then we need to come to what we call claims and evidence. I can claim that as mass goes up volume goes up or so as. Now their

> data, it was very interesting, now not unexpected, but as individual groups their data was all over the place as it relates to density and volumes. So then they made claims and evidence. While I can claim that there is no relationship, or sometimes it goes up, sometimes it goes down and then we do a thing called claims shared. Where I take the white board and we do a huge class data table. (Interview, North, 2012, November 7)

Modeling Instruction provided a predesigned lab in which the students followed step-by-step procedures to collect data in small groups, share the data with others in a board meeting, and develop a class model of the density concept. As described by Ms. North in the previous quote, the lab was re-designed to include writing heuristics so that students determined their own questions and was required to provide claims and evidence.

As the year progressed, Ms. North's use of the Modeling Instruction curriculum underwent further adaptation.

> I'm changing my instruction based on what I learned this summer, but I'm incorporating what I use that's called science writing heuristic. Now in light of time I am going to be skipping Modeling curriculum to go back to this, but employing Modeling technique. (Interview, North, 2012, November 7)

In this statement, Ms. North explained how she had stopped using the curriculum provided to her during the professional development in favor of continuing with writing heuristics. She further explained the instructional technique taken from Modeling that continued to be useful. "I am doing a lot more white boarding than I was and so I try to take opportunities, even you know, not following the curriculum per se" (Interview, North, 2012, November 7). Ms. North further clarified the curriculum change with a specific example of how the techniques from Modeling Instruction were still being employed in the creation of future lesson planning.

> Right now we are going into the history [of] the atom. Basically this is a stand-and-deliver kind of thing. And then we are going into parts of the atom, and I have some activities that we could do and can be white boarded. Some of those same pedagogical skills we used that reflect modeling I am just going to try to bring that in as much as I can. (Interview, North, 2012, November 7)

The history of the atom and the parts of the atom were both topics that were not included in the Modeling curriculum. The adaptation was the use of whiteboards with her previously developed classroom activities. Ms. North integrated the board meeting technique learned in the Modeling Instruction professional development in concepts not explicitly included in the Modeling curriculum.

Facilitation.

Facilitation of productive classroom discourse was a key component to Ms. North's instructional techniques. Ms. North indicated that the use of whiteboards assisted in her ability to examine student understanding, as in the following quote.

> It helps me and it helps them [the students] to see what other people are thinking. And that's kinda what my goal is for them to see how different, different ways of

> looking and thinking and then coming to consensus about what we think is happening. (Interview, North, 2012, September 26)

This desire to facilitate collaborative understanding indicated that Ms. North assisted her students in the discovery of individual perspectives. The interactions that occurred during white boarding sessions allowed Ms. North to observe students, which in her words "made me more aware of how students are learning together" (Interview, North, 2012, November 7), and "it helps me to have a better understanding of what they know" (Interview, North, 2012, September 26). Ms. North felt that the interactions during the board meeting were helpful to students because "it gives them an opportunity, if I try to pull it from them, why they think the way they do, and to identify misconceptions" (Interview, North, 2012, September 26).

In order to facilitate student understanding, she structured a learning environment designed to "pull it from them." This ability that Ms. North had deliberately cultivated was noted during observations as having successfully implemented productive talk moves. When asked what had prompted her to use these techniques she replied,

> I felt like I needed to work on [discourse], but that is something that I tend to do. I think it is good when students work in groups, and I think it's good when they ask questions to ask them back and to keep coming up with reasons for why. (Interview, North, 2012, November 7)

In this quote, Ms. North indicated that facilitation of classroom discourse was an intentional goal of her interactions with students.

Pacing.

Ms. North was concerned about the amount of time required to complete the Modeling Instruction curriculum. "You know learning takes time, and learning this way takes time. It's probably impossible to include it all. There are some things that I won't ever get to here" (Interview, North, 2012, November 7). This quote indicated that Ms. North felt that concepts normally included in her classroom content were going to be sacrificed due to the amount of time required for learning. She further supported this difficulty by stating, "I am very concerned about not being able to cover the material that I think is going to be important" (Interview, North, 2012, November 7).

The amount of time spent on the first unit of the Modeling curriculum (i.e., the density unit) was a difficulty for Ms. North. In the initial interview, she plainly stated, "There is a huge amount of time spent on density that I won't spend" (Interview, North, 2012, September 26). Even with the intention to cut the time spent, in the follow-up interview she reported that, "Density [instruction] took almost a whole six weeks" (Interview, North, 2012, November 7). This inability to maintain a familiar pace caused Ms. North to doubt moving forward with the established Modeling curriculum. "I was very conflicted about whether to go into, I would only be in unit two right now. And part of the issue is, I am feeling a pressure on the time" (Interview, North, 2012, November 7). In addition to feeling the time pressure, Ms. North was unsure of the curriculum because of her prior experiences. "Scope and sequence of the way the chemistry flows, there's a lot more emphasis on areas that I have not put emphasis on before" (Interview, North, 2012, September 26). The conflict that Ms. North was having in regards to pacing was strongly connected to her ability to cover important content.

Content.

Ms. North observed that the Modeling Instruction curriculum did not provide instructional materials for all of the content typically encompassed in her high school chemistry courses. The second unit in the Modeling curriculum that Ms. North was debating on implementing was designed to explore gas laws. In the following quote she expressed her concern with the design.

> The standards that we have, for example regarding gas laws is like one. While there are many more that deal with history of the atom and electron configuration and so forth. The value of that [atomic theory], the personal value that I place on that; chances are they won't ever use electron configuration. I mean, why is that important? Other than to understand the value of reactivity based on electrons, which is huge based on the concept of things. (Interview, North, 2012, November 7)

Ms. North identified a large difficulty she was experiencing in her implementation given that a concept she valued in the development of student understanding was not included in the curriculum. She explained,

> Having a better understanding of you know, everything, really depends on electrons in terms of chemical reactions and what's happening. There's not a lot of emphasis in that area. So to me a weakness [of the Modeling Instruction

> curriculum] is maybe focusing too much in like the density area. (Interview, North, 2012, September 26)

In addition to identifying areas that were not included, Ms. North noted that ultimately tough choices between content that could be taught using the Modeling Instruction curriculum and content the state valued in the curriculum. “I have to make decisions, and I haven’t come to those conclusions, about what am I going to do with electron configuration” (Interview, North, 2012, September 26). Ms. North weighed a lot of variables when she was making the choice of content as seen in the following excerpt.

> When these kids go to college that they’re going to be expected to know about the atom, and about the electron configuration, about the interactions, to be able to get into chemical bonding, balancing chemical equations, and while from a conceptual stand point I can see definitely the value of going into unit two with gas laws, I am very concerned about not being able to cover the material that I think is going to be important. (Interview, North, 2012, November 7)

As indicated in the following statement, Ms. North was concerned about the foundation her students acquired for future studies in science.

> So as a teacher we’re asked to identify what’s essential and what’s not essential ... Because I keep in touch with students that come back, [after] they go to college. [I ask] what’s going to be in those freshman chemistry courses or what are they going to have to remember in chemistry that they’re going to be using in Biology, those kinds of things. It’s important for me to prepare them…Periodic table

> trends, those kinds of things, being able to use that [information from the periodic table related to electron configuration] as a tool to be able to go on and balance equations. (Interview, North, 2012, November 7)

The content that was covered in the Modeling curriculum, emphasized material that Ms. North felt was included in her previous instruction. “Whereas the reasoning that they are going to get from gas laws is very good [using the Modeling curriculum], but that is something that I do cover [in my regular curriculum]” (Interview, North, 2012, November 7). The reasoning to which she eluded was a result of examining chemical interactions at the particulate level. Ms. North explained that “looking at things at the particle level in this way I have not done before. And so that part definitely has changed” (Interview, North, 2012, September 26). This change of perspective to the particle level was difficult for Ms. North, because of the gaps in content knowledge she associated with Modeling Instruction. “Some of the material that’s left out, that’s never covered, periodic table trends, those kinds of things being able to use that as a tool to be able to go on and balance equations and stuff” (Interview, North, 2012, November 7).

In the initial interview Ms. North voiced her appreciation for chemistry not being one of the classes that had an end of course exam, because the Modeling curriculum did not provide instructional material for all the content associated with state standards.

> I’m a newbie to Modeling; and so I’m learning and finding some very valuable things. There are things that I’m still a little conflicted about. How am I going to

cover these standards? And I'm thankful that it's not a tested area. (Interview, North, 2012, September 26)

In addition to the difficulty Ms. North was already having with the content coverage being incomplete for preparing her students for future learning, she was later informed that her students would soon be held accountable for content standards by a state mandated assessment. "You may or may not have heard, but we got the email that they are going to be piloting the chemistry end-of-course test this year" (Interview, North, 2012, November 7). The decision to stop implementation of the Modeling Instruction curriculum for Ms. North was directly linked to her inability to provide complete content coverage.

Student Understanding.

Ms. North expected her students to master content that she presented in her class. Ms. North indicated that instructional techniques used in the Modeling Instruction curriculum assisted in developing student understanding. She communicated throughout the final interview that one technique from the Modeling curriculum she would continue to implement was white boards. Her use of this technique was demonstrated in the final observation, which Ms. North did not consider to be a typical day in her class. "The students had not mastered significant figures and accuracy and precision of lab equipment - and so that is something I consider very important; so I was backing up and doing some more practice" (Interview, North, 2012, November 7). In this statement Ms. North expressed that her desire for the students to master a specific concept required her to allow students more time to practice problems related to that content. The students used white boards to share answers during the class which allowed Ms. North to identify areas where students could assist one another in developing content knowledge. When questioned why she explained,

> It's not about me giving information, it is about them discovering learning and making sure that their understanding is not just superficial. That they can be able to explain in their own words, to demonstrate understanding, and that can be done when this student, explained the concept to another student. I can evaluate how that student understands, why they think the way they think. Then when we did a different problem on the board, then that student is able to explain it to me. He said it in his own words, that were different from this student, but it showed me that ok, he was on the right track, he was getting it. So it helps me to identify what they understand. (Interview, North, 2012, November 7)

Ms. North also expressed that white boarding helped assist students developing an in-depth understanding of terms.

> You know, they can spit out the law of conservation of mass, or oxidized, or whatever. But do they really know what that means? They're throwing out terms. We sometimes think well they know what they're talking about, but they don't always. They are just throwing out jargon. So white boarding helps me to identify what they know. (Interview, North, 2012, September 26)

Student Participation.

Ms. North did not report difficulties in student participation. She engaged her students in conversations with one another during instruction. She used productive talk moves and questioning to include students during class. Ms. North effectively taught students how to communicate thoughts and ideas related to the data. She recalled the following example.

> We white boarded [the density model] and there were some misconceptions [in regards to the data presented] that were identified. I didn't have to say a thing. They [the students] saw that, and they talked about that. They employed those positive discussion procedures -yeah it [the student conversation] was good. (Interview, North, 2012, November 7)

In the previous quote Ms. North summarized a student experience that occurred during a whiteboard meeting. She indicated that student participation exceeded her expectations.

Student Ability.

Although Ms. North felt that her students in every class were engaged, she noted some differences between her classes in regards to student ability. "I'm finding that this particular class my third period class. I would say that the academic level of the students in general is lower. I have three chemistry classes, than my other two." (Interview, North, 2012, September 26). The observation of Ms. North's classroom took place during her third period class. One group in particular had a misconception written on their white board. The students had a difficult time expressing their reasoning for the answer was presented. Ms. North engaged other students in the discussion to help develop their understanding. In reflecting on this she explained,

> I'm seeing that it took a long time to get through the boards and for me to have a sense that they knew what was going on, and understand what they thought. Where my other groups, my other two classes it was much more evident what they knew and why they knew. Not that there weren't misconceptions, but I was just able to get it out of them more easily. [They were] better at expressing and explaining, I guess. (Interview, North, 2012, September 26)

Ms. North stated that the reason two classes were better at creating a collaborative understanding was their ability to effectively communicate what they knew about the content. The gap in understanding was identified and addressed by Ms. North during instruction; however, she acknowledged that the imbalance was addressed with additional time during the board meeting.

Student ability was also a factor that Ms. North attributed to the large amount of time spent in her classroom working with students on concepts that she felt her students should have mastered prior to chemistry. "Up into density, this would be wonderful for the physical science arena more so than chemistry, because I'm thinking that they should have a better understanding - but they don't" (Interview, North, 2012, September 26).

Social.

Ms. North was the only teacher at her school that attended the Modeling Instruction professional development. She communicated that having more individuals in her educational community aware of the curriculum would have benefited her in continued implementation.

> There's not anyone else Modeling [or teaching chemistry] and that's one thing. I know that some schools are doing Modeling all through their science department, you know or their district that would be amazing. I am sold on the reason and the way that it is done, with some adjustments as needed. And the kids obviously like it very well, but in order to get the content covered. I am all about this, you know depth as opposed to breadth, but when you are held accountable. (Interview, North, 2012, November 7)

The accountability for content combined with the length of time needed to use the Modeling Instruction curriculum were not topics that Ms. North had not communicated to others prior to attending the follow-up workshop. Ms. North explained her apprehension about meeting with others as follows.

> I'll be honest I had just made the decision that I am changing the way I am doing this, and I am feeling badly about it. And then thinking I am ready to be beaten up over making this decision, and that's not what it was about at all. I appreciated having this sheet on facilitating classroom discourse and looking and reviewing and it was very positive. And I needed that especially after going through that

> decision [the decision to stop her implementation of the Modeling Instruction curriculum]. (Interview, North, 2012, November 7)

Ms. North was appreciative of the time that she had to interact with others that attended the professional development. She enjoyed that the workshop continued her learning.

> I did enjoy meeting together. People are busy and it's hard. And you guys made that special exception to get the rest of us in. I really appreciate that. I enjoyed it, and it's reenergizing. It's a learning process for me to come together that way. (Interview, North, 2012, November 7)

Ms. North stated that while she did not have people at her school that were using Modeling Instruction having additional educators involved in the curriculum would be awesome. The bad feelings that Ms. North experienced related to changing her instructional practice were mitigated through meeting with others in the follow-up workshop.

Instructional.

Ms. North instructed her students using a student-centered approach to teaching prior to attending the Modeling Instruction professional development; she adapted her instruction to incorporate techniques presented in the Modeling Instruction professional development. In the initial observation Ms. North had her students participate in a laboratory experiment. In the experiment student had to determine properties of air using the normal lab equipment, as well as a balloon and straw. The students worked to find data that helped them understand gases. As an example one student excitedly stated, "the balloon is heavier when it is inflated, air has mass" (observation, North student, 2012, April 21). The familiarity with inquiry instruction allowed Ms. North to transition naturally to Modeling. "[Productive talk moves are] something that I do anyway - a lot of what we do in Modeling is something that comes very natural to me" (Interview, North, 2012, November 7). Although she expressed familiarity with the concepts reviewed during the follow-up workshop, Ms. North shared positive feedback on the content of the follow-up workshop. "I appreciated and enjoyed that session because it refreshes those things that you feel like, you know. Oh yeah, I need to be working on that" (Interview, North, 2012, November 7).

The need to work on instructional techniques was not abandoned by Ms. North. Even after making the decision to discontinue use of the Modeling Instruction curriculum she continued to reflect on the impact to student learning.

> I really like the pedagogy behind the Modeling and the philosophy of how students learn through this process. And so those are the kinds of things that I am going to work very hard at continuing to implement. And so it's made me more aware of how students are learning together. (Interview, North, 2012, November 7)

Although Ms. North had decided to adapt her implementation of Modeling Instruction curriculum she embraced the pedagogy and philosophy.

RTOP.

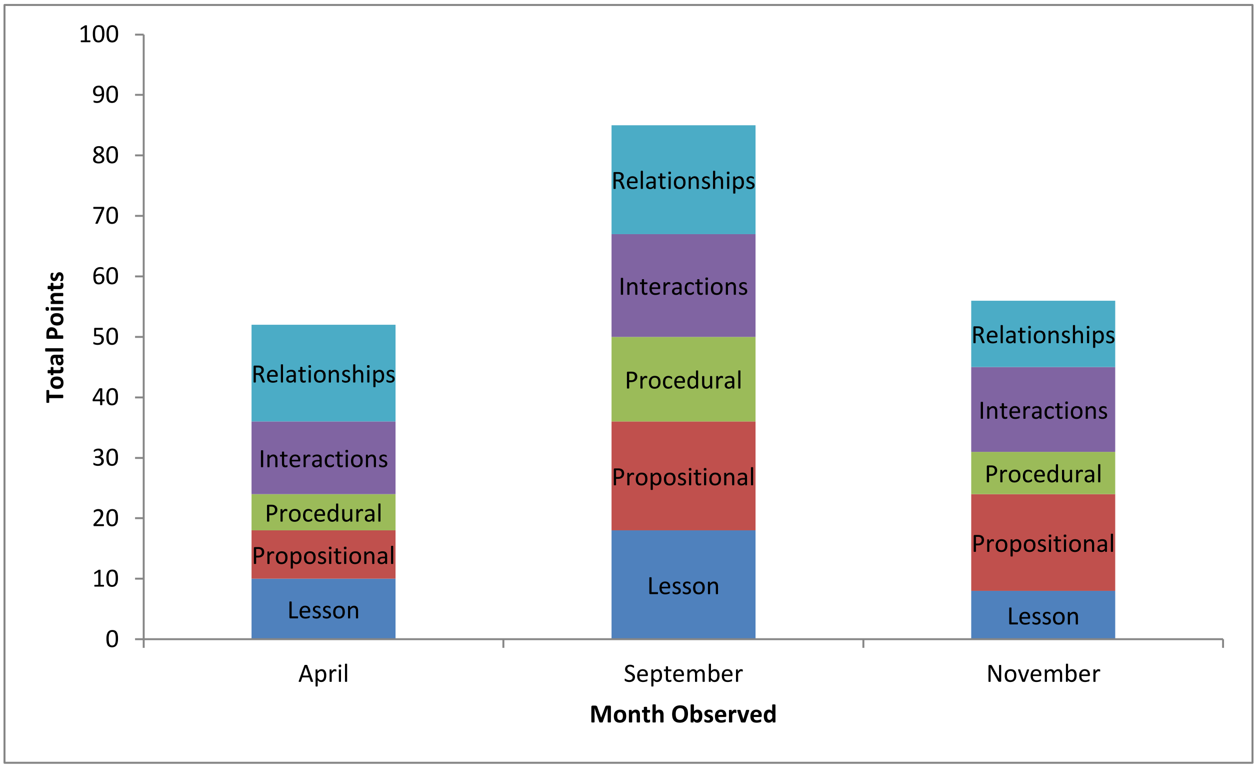

Figure 3. Ms. North scores from each RTOP divided into five categories. From bottom to top: lesson design and implementation, propositional content knowledge, procedural content knowledge, communicative interactions, and student teacher relationship.

The RTOP scores for Ms. North, as seen in Figure 5, were substantially higher than the other teacher that participated in the study in every observation lesson. The scores that Ms. North earned on the initial observational lesson indicated that she was experienced in promoting student-centered learning environments prior to the Modeling

Instruction professional development. Interestingly the scores for Ms. North increased in every RTOP category in the post professional development observational lesson, and all categories decreased in score as a result of the final observational lesson. As previously stated, Ms. North had worked to implement the Modeling Instruction curriculum into her instructional practices, and discontinued those practices before her final observational lesson. The field notes were analyzed to determine behaviors that may have contributed to the increased scores, and results for the categories of lesson design and implementation, propositional content knowledge and procedural content knowledge will be discussed further. Ms. North's score for both content areas of the RTOP and the classroom culture category of communicative interactions were higher from the final observational lesson than the initial observational lesson, while the scores in the categories related to student/teacher relationships and lesson design and implementation were lower.

Lesson design and implementation.

The lessons that Ms. North conducted were each considered to be student-centered, although a marked increase occurred in the lesson design and implementations section in the post professional development observational lesson. The initial observational lesson was an exploratory lab experience in which the students designed procedures and collected data. The post professional development observational lesson was a board meeting technique from the Modeling Instruction curriculum designed for students to interpret results previously collected. The final lesson was a review in which the students engaged in discussion pertaining to practice problems the students completed during class. Each lesson design and implementation will be further explored.

The initial observational lesson was designed and implemented to be student-centered, Figure 3. Ms. North demonstrated components of each statement contained within the lesson design and implementation section of the RTOP. Ms. North employed instructional strategies that assessed students' conceptual understanding of chemistry in. She tried to gain clarity of student understanding as noted by Observer J. "[The] teacher would continue to ask probing questions until students could completely justify their answers; however, no dialog was facilitated among students" (Field Notes, Observer J, 2012, April 13). The use of questioning, during the lesson observation to engage students, was noted by both observers. "The teacher used questioning to point out misconceptions" (Field Notes, Observer J, 2012, April 13). Ms. North encouraged students to share their ideas which indicated respect of student knowledge. "[The] teacher asked individual groups to explain what [their] group findings were" (Field Notes, Observer J, 2012, April 13). Ms. North was noted interacting with groups in the following statement by Observer J. "[Group] discussion about comparison work [as a force] through wording [to determine that], air is compressible! [The] suction discovery [was a result of] students' answers [to] questions about suction and compressibility" (Field Notes, Observer J, 2012, April 13). At the conclusion of class Ms. North was noted expressing her desire to continue student interaction. "[Your] issue we need to revisit next time" (Field Notes, Observer Q, 2012, April 13), indicated the respect of student knowledge that is a fundamental part of the lesson design and implementation section of the RTOP.

Ms. North also demonstrated teacher practices that related to engaging students in a learning community during the initial observational lesson study another key aspect of the lesson design and implementation section of the RTOP. Ms. North was noted by both observers for engaging the students in the assessment of homework. “[Ms. North] started [the class] with homework grading time (teacher walks around). Students read answers aloud (traded papers)” (Field Notes, Observer Q, 2012, April 13). Ms. North was noted for engaging students with one another by forming groups, before working in the lab students “numbered off to form groups” (Field Notes, Observer Q, 2012, April 13). Ms. North expected her students to engage as members of a scientific learning community as noted by Observer J. The students were expected to provide the following information “five procedures, observations and claims about your evidence discovering properties of gases” (Field Notes, Observer J, 2012, April 13). Ms. North exhibited techniques that valued student results. “[The] teacher [was] asking questions, to bring out a summary [of student findings]” (Field Notes, Observer Q, 2012, April 13).

The lesson design and implementation category of the RTOP includes student exploration preceding formal presentation and the promotion of student problem solving with alternate modes of investigation. The lab assignment that students completed during the initial observation lesson was noted as having a focus of exploration. Ms. North wrote the following title on the board for students to record. Observer Q noted the following, “[In your] notebooks [write] Lab 10 discovering properties of gases, Air! [Students were asked to] describe procedures. [The main] idea [of the lab was] to use [a] syringe and balloon” (Field Notes, Observer Q, 2012, April 13). The students were observed using multiple modes of investigation. “[The students were] discussing a procedure to do, [and the] teacher [was] letting students try something interesting over the sink” (Field Notes, Observer Q, 2012, April 13). Ms. North was observed encouraging students to investigate alternative methods for experimentation. “[Ms. North] redirected [students investigation] to comparison of water. [She asked students,] ‘What could you do for an experiment?’” (Field Notes, Observer J, 2012, April 13). The following observation by Observer Q indicated that Ms. North did not encourage students in the same way a Modeling Instruction lesson would. “The students worked with data and were required to draw conclusions from their explorations, but didn’t really extend [to a model] from there” (Field Notes, Observer Q, 2012, April 13).

The lesson design and implementation section of the RTOP also emphasized the importance of allowing students to determine the focus and direction. Ms. North was observed providing structure for students during the initial observation lesson that encouraged student direction. As noted by Observer J, “[Ms. North required students to list] each procedure then test, give claims and evidence. [More specifically she expected students to] show procedures, observations, [and] what was claim/evidence, [in the lab report]” (Field Notes, Observer J, 2012, April 13). The open design of procedures allowed for students to determine how they wanted to proceed with the data collection in the lesson. Additionally as students collected data Ms. North encouraged them to expound upon their results. Observer J noted two separate topics Ms. North explored with her students after they had used words such as suction and vacuum. “The [students] idea of a vacuum was challenged. Particularly how it [the vacuum] was formed… [Additionally, Ms. North encouraged students to conceptualize] suction, [by] developing an understanding of which forces were acting [within the syringe]” (Field Notes, Observer J, 2012, April 13). Ms. North’s lesson design and implementation was a good representation of that of an average student-centered teacher.

In the post professional development observational lesson the scores that Ms. North received in the RTOP category of lesson design and implementation were perfect. The lesson as previously stated was one that Ms. North had adapted from the Modeling Instruction. Ms. North demonstrated mastery of instructional techniques presented during the Modeling Instruction professional development. Similar to the previously observed behavior Ms. North improved student conceptions by ascertaining the students’ current conceptual understanding. As noted by Observer J, “[The] board meeting starts, teacher questioned each group” (Field Notes, Observer J, 2012, September 26). The following statement provides an example of Ms. North attempting to determine the course of student knowledge. “[The] teacher helps students add their diagrams to make it better by using input from class dialogue. Other students [were] making suggestions [a student] asked another student to supply evidence, ‘How would you know that?’” (Field Notes, Observer Q, 2012, September 26). The observations provided examples of the importance

Ms. North placed on student preconceptions a key component of the lesson design and observation section of the RTOP.

Ms. North was observed engaging students in a learning community in the following example.

> [The] teacher gives assignment: students get in groups to whiteboard. [Ms. North is] answering questions on drawing particle diagrams. She has directions on the main board. [Ms. North] goes over how they agreed to represent particles. [Ms. North] divides up students, [saying] "same groups of three as before". (Field Notes, Observer Q, 2012, September 26)

In the Modeling Instruction observational lesson Ms. North was noted as being able to engage students in large group conversation about their individual results which could account for some of the increase to the lesson design and implementation section of the RTOP.

Ms. North was also observed displaying practices which could have further contributed to her increased score as student exploration occurred before the presentation of content, and students were encouraged to value perspectives other than their own for problem solving.

> [The] teacher leads groups in figuring out that Alka-Seltzer and water create a new gas. That gas is not Alka-Seltzer…Quite a few misconceptions were revealed when the teacher gave the students the chance to explain their thinking and their diagrams. (Field Notes, Observer Q, 2012, September 26)

Observer Q noted that Ms. North used the alternative thinking patterns of her students to engage students in a learning community that encouraged exploration of data to determine explain their results. After going through each group Observer J noted the following. “[Ms. North tells students], ‘Quickly have a seat and clarify your thoughts on what happened, give evidence of what happened’” (Field Notes, Observer J, 2012, September 26). Ms. North was also observed encouraging students to engage in alternative modes of investigation by using white boards and particle drawings. As noted by Observer J, “White boarding instructions for lab and particle drawing [were given]. [The] students recalled how to draw particles” (Field Notes, Observer J, 2012, September 26). The student investigation mentioned in the field notes used by Ms. North also attributed to an increased score in the lesson design and implementation section of the RTOP.

The previous observation of Ms. North had revealed that she encouraged students to provide focus and direction during her lesson. The use of white boards was noted in the following excerpt from Observer Q. “[The teacher] times students for ten minutes. [As] students [are] finishing up, teacher asks that they circle up. [A] Student [asked a] question, ‘Would there be unmixed particles?’ Teacher [asked class], ‘What do you guys think?’[The students provide an answer. Ms. North asks,] ‘Do you all agree?’” (Field Notes, Observer Q, 2012, September 26). As demonstrated in the previous example, Ms. North was observed allowing students to construct their personal understanding. “The teacher probed just enough to ensure that students truly understood and weren’t just saying what they thought she wanted to hear" (Field Notes, Observer Q, 2012, September 26). The previous examples provide support for the maximization that occurred in the lesson and design category of Ms. North's RTOP score.

In the final observational lesson Ms. North earned her lowest score in the lesson design and implementation section of the RTOP. As previously noted the lesson was not designed based on instructional techniques from the Modeling Instruction professional development. Ms. North was still noted assessing students' prior conceptions. "[Ms. North] asked students to raise hand if they 'feel they are understanding'. [The] teacher goes over answers to the worksheets; the groups had worked on [during class]" (Field Notes, Observer Q, 2012, November 7). The students were again noted by both observers as being engaged in a learning community with group work and assessing peer assignments. "[The] students get out homework, trade, teacher announces answers clarified how to grade and what is acceptable…The students worked collaboratively in small groups to complete a worksheet which extended their understanding about significant digits. (Field Notes, Observer Q, 2012, November 7). Ms. North was observed encouraging students to participate. "[The] teacher was calling on people so they paid attention. [The] students worked through problems on worksheet in groups of four's. [The] teacher walked from group to group [and] asked lots of questions (Field Notes, Observer J, 2012, November 7).The preceding examples provide evidence for Ms. North maintaining a learning community a key component of the lesson design and implementation section of the RTOP during her final observational lesson.

The areas in which Ms. North did not score as well involved the lesson promoting exploration before presentation of content, encouraging alternative modes of investigation, and student directed discussion. The lesson was explained in the following excerpt. “[Ms. North] begins working through some of the problems. [She says], ‘Now we are going to practice accuracy and precision in groups’. [Ms. North] explains [the] worksheet [to students] (Field Notes, Observer Q, 2012, November 7). In the field notes Observer J mentioned, “This was a review lesson on significant figures, not a typical exploration lesson for this teacher” (Field Notes, Observer J, 2012, November 7). The lesson was not designed to encourage alternative modes of problem solving and the focus and direction was noted by Ms. North as being accuracy and precision. Ms. North was noted as involving students during the lesson in the following excerpts. “[In order for Ms. North] to give ‘immediate feedback’, [the] teacher went through each question [with which] students had difficulty. [Ms. North was] asking individuals during lecture, ‘Why are significant figures important?’” (Field Notes, Observer J, 2012, November 7). “In asking student how they got an answer the teacher discovered a misconception and addressed it (Field Notes, Observer Q, 2012, November 7). The previous examples provide support for Ms. North earning a score in the lesson design and implementation section on her final observational that was slightly lower than her initial observational lesson score, although still a moderate score overall.

Content.

Propositional knowledge.

Ms. North earned the maximum possibly points in the RTOP category of propositional content knowledge from the post professional development observational lesson. Key areas of the propositional content knowledge category RTOP that remained consistently high through all observational lessons pertained to Ms. North displaying a solid grasp of fundamental chemistry concepts during each lesson. In each lesson the observers noted Ms. North's ability to question students, this ability indicated that Ms. North had a strong conceptual understanding of chemistry as she demonstrated an expert ability to guide student learning. Ms. North was quoted often by researchers as expecting evidence to support student conceptualization of chemistry content. Observe Q noted her persistence in obtaining student knowledge.

> [The] teacher requires evidence, "How do you know?" When [the] student said, "Air flows from high to low pressure". [Ms. North asked], "How do you know air has mass?" [The] student replied "You told us". [Ms. North stated] "No, I didn't". [Student] "Other teacher told us", [to which Ms. North asked] "How can you know if air has mass?" (Field Notes, Observer Q, 2012, April 13)

The content of each lesson included concepts that were considered fundamental to chemistry. In the post professional development observational lesson Ms. North was noted as having asked students "[Was there a] 'chemical reaction or not?', and 'Does the number of chemicals change?'" (Field Notes, Observer J, 2012, September 26). In the final observational lesson Observer Q noted, “[Ms. North] teaches about certainty and accuracy in measurement” (Field Notes, Observer Q, 2012, November 7). The examples from observer field notes helped to establish the consistency with which Ms. North presented lessons in which her comprehensive understanding of chemical concepts was easily identified. There was greater fluctuation in other areas pertaining to the category of propositional content knowledge.

Coherent conceptual understanding was a key area of propositional content area that was demonstrated more in the lesson observations following the professional development than in the initial observational lesson. Initially Ms. North was noted for keeping students on the topic while discussing gaseous phase interactions. Observer Q noted, “[Ms. North said], ‘the bonds- were not going that deep yet’” (Field Notes, Observer Q, 2012, April 13). Students were noted trying to develop a coherent conceptual understanding in the following excerpt, “conversation between several students about molecules being less dense [as a gas]” (Field Notes, Observer J, 2012, April 13). In the post professional development observational lesson Ms. North was noted assisting in the development of coherent student understating. “She usually used questioning to get the students to a point where they were explaining things accurately (Field Notes, Observer Q, 2012, September 26). Ms. North was noted asking for students to help explain observations in an attempt to construct a coherent understanding. “[The] student [replied], ‘It’s plasma’. [The] teacher [followed-up with] questions [directed at the] student [to explain] on a particulate level” (Field Notes, Observer J, 2012, September 26).

At the conclusion of the post observational lesson Ms. North was noted encouraging students to reflect on and connect the data to the results discussed in the board meeting. “She passed out [a] homework sheet- worksheet [that] requires students to answer question/draw pictures related to what they’ve done today” (Field Notes, Observer Q, 2012, September 26). Observations continued to indicate that Ms. North emphasized a coherent conceptual connection even when presenting accuracy and precision content in the final observational lesson, although not to the same extent as seen during the post professional development observational lesson. “The teacher used questioning to point out misconceptions about why significant figures are important, particularly as they pertain to lab data” (Field Notes, Observer J, 2012, November 7).

The area that pertained to elements of abstraction another key aspect of the propositional content knowledge category of the RTOP was noted multiple times during the post professional observational lesson by researchers. In the following excerpt Observer J noted the way in which Ms. North used questioning to highlight student data interpretation. “[Ms. North asked], ‘How do you know it is a chemical change? Why do you agree? [She explained] How do you know it is critical – must be based on evidence – direct or inferred’” (Field Notes, Observer Q, 2012, September 26). Observer Q noted, “in a way the whole lesson was about large ideas such as forms of matter and chemical and physical reactions (Field Notes, Observer Q, 2012, September 26). Ms. North was noted emphasizing the importance of an abstract conceptualization. Observer J noted, “[Ms. North stated that reactions were] ‘complicated and abstract’. [Students were instructed to] ‘Come up with a model of what it looks like’”(Field Notes, Observer J, 2012, September 26). The particulate representations drawn by each group allowed for students to develop a stable construct related to abstract concepts. “The teacher used student ideas about the concepts to generalize by moving from a submicroscopic particle diagram to larger solids such as the table or steel wool” (Field Notes, Observer J, 2012, September 26). The observations indicated that Ms. North’s elevated score in propositional content knowledge can be attributed at least in part to her ability to provide a wide view of the content being presented in the post professional development observational lesson.

The area of propositional content knowledge that pertained to connecting content to real world/other disciplines was once more noted as being more pronounced in the post professional development observational lesson. Observer Q noted, “[Ms. North asked], ‘What did you learn?’ [Student replied] ‘Our group proved air has mass’” (Field Notes, Observer Q, 2012, April 13). Alternately the entire discussion of chemical reactions, from the post professional development observational lesson, revolved around house hold objects such as Alka-Seltzer and steel wool, supporting the rationale for a higher score. The researchers noted that Ms. North attempted to relate the topics of her final observational lesson. “[The] teacher goes over how to use calculator, [specifically] scientific notation…She did try to help the students see the importance of the topic (significant digits) and kept relating it to concepts of accuracy and precision in specific instruments of measurement (Field Notes, Observer Q, 2012, November 7). Observer J also noted, “While she did not generalize the lesson to a broader application, because the lesson focused on sig figs. She did talk about how mathematics does not use the same rules (Field Notes, Observer J, 2012, November 7). The observational data provided from the researcher field notes once again helped to clarify the superior scores obtained by Ms. North in the category of propositional content knowledge.

Procedural knowledge.

The category of procedural content knowledge on the RTOP contains statements that pertain to student activity during the observational lessons. Ms. East’s earned her highest score in this category in the post professional development observational lesson, with the other two observations attaining scores that were lower, but similar to one another. There were several areas of improvement noted in the category of procedural content knowledge. Of particular interest were the observations that pertained to the area of procedural content that examined student representations of phenomenon. The only lesson, in which researchers noted multiple representations presented by students, was during the post professional development observational lesson. Observer Q noted that, “students went almost immediately to lab desks to work, then made a circle around the outside of the seats for the white board presentations” (Field Notes, Observer Q, 2012, September 26). Ms. North’s expectations were noted in the following statement. “She talked about the importance of explaining what they [the students] really mean, so she knew what they were thinking – not just assume what they were thinking (Field Notes, Observer Q, 2012, September 26). The variety of student representation an area that is a part of procedural content knowledge was notably absent in the final lesson observation. "The students were sharing ideas amongst the small groups that they worked in, to complete the assignment, but did not present their ideas to the full group (Field Notes, Observer Q, 2012, November 7).

Another area of procedural content knowledge that may have contributed to the score changes exhibited by Ms. North in this category was active engagement. Ms. North attempted to keep her students engaged and actively thinking about what they were supposed to learn. In the initial observational lesson Observer Q noted, "[Ms. North asked] 'what procedures do you have?' (Field Notes, Observer Q, 2012, April 13). Questioning was a key technique observed to keep students present in the classroom. "[The] teacher asked students to explain answers often, even when the correct answer was given" (Field Notes, Observer J, 2012, April 13). The techniques employed by Ms. North were not always successful as noted by Observer Q.

> This group is never on task. Hasn't touched materials yet other groups seem to be working. [Five minutes later the] group [is] starting to do something. [The] teacher approaches [a] nearby group [and] asks them to show her what they have done, what do they observe, why? [Three minutes later] [The] teacher comes to this group. They're eager to show her a procedure, but it is kind of off the cuff. [The] teacher accepts the procedure and questions them to explain what they observe and why. (Field Notes, Observer Q, 2012, April 13)

Although the group was noted as not being on task they were able to engage when Ms. North directly questioned them. In the post professional development observational lesson the students shared ideas during a board meeting, effectively making the entire class a group. The ways that Ms. North engaged students became more inclusive as noted in the following excerpt, "[The] teacher is confused about their method and questions them. Helpful to see what others are thinking so you can improve your thinking. Student [stated], 'this is legit chemistry" (Field Notes, Observer Q, 2012, September 26). The increased interactions would support a higher score in procedural content knowledge. Alternately when working as a class in the final observational lesson Ms. North continued to use questioning, but rather than directly asking students was noted saying, "please add input while working problems" (Field Notes, Observer J, 2012, November 7).

The area of student reflection within the procedural content knowledge category was most noted in the post professional development observational lesson, and not noted in the final observational lesson. "Preconceived ideas, but deal directly with observations, claims and evidence as you go (Field Notes, Observer J, 2012, April 13) Teacher reminds students of what they saw in the lab, why? (Field Notes, Observer Q, 2012, September 26) the students completed work in lab previously and used the data to draw conclusions and build ideas. (Field Notes, Observer J, 2012, September 26) When you measured the steel wool what was the mass? Sure, but do you think it was supposed to be more? (Field Notes, Observer J, 2012, September 26) The students worked collaboratively for white board presentations. When one particular question came up different on two boards the students were asked to collaborate for understanding (Field Notes, Observer J, 2012, September 26) Observations were collected that highlighted the change in the category of procedural content knowledge that related to the intellectual rigor displayed during the observational lessons. Ms. North was noted challenging student ideas on several occasions during her initial observational lesson. “Student with the wrong answer, [Ms. North asked] ‘why?’ [She] encourages discussion [to develop student understanding]” (Field Notes, Observer Q, 2012, April 13). “[The] teacher was very skilled at questioning, [Ms. North] required students to back up their statements and explain the “why’s” behind things (Field Notes, Observer Q, 2012, April 13). The following excerpt from Observer J exemplifies the way Ms. North used questioning to challenge her students understanding. “[Ms. North asked] ‘How do you know what’s in there?’ [She] sucks air from balloon… [In conclusion Ms. North asked] ‘What is the observation? [Name] one thing about [the] property of air-has mass- review, how do you know?’” (Field Notes, Observer J, 2012, April 13).

Ms. North was noted challenging student ideas more often in the post professional development observational lesson.

> [Ms. North asked] “What does this mean? Think about a better description, think critically about it. Describe things as accurately as possible”… [The] teacher explains that students need to clarify their words and be clear in their explanations for assessments. (Field Notes, Observer Q, 2012, September 26)

Additionally Observer Q noted that students also participated in the discussion. “The students questioned others ideas. The teacher often tried to get the students to question each other, and agree or disagree. It happened a number of times” (Field Notes, Observer Q, 2012, September 26). Observer J noted that using correct chemistry terminology did not stop Ms. North from developing a more thorough conceptual understanding. “[The] teacher used questioning to point out misconceptions – in particular what students meant by oxidized. It was very interesting to see the students would continually & correctly use the word without understanding the process (Field Notes, Observer J, 2012, September 26). The level of understanding that Ms. North was able to communicate through questioning appeared to be more in-depth in the previous examples supporting the higher score earned in the post professional development observational lesson. Although the interactions were not as challenging to student ideas during the final observational lesson Observer Q noted that she continued to investigate student knowledge through questioning. “The teacher asked higher-order thinking questions regularly. She asked questions that seemed to scaffold students’ understanding to the point that they understood fully” (Field Notes, Observer Q, 2012, November 7).

Mr. South.

Background.

Mr. South was a Caucasian man in his twenties. At the time of the study, he taught two sections of standard Chemistry, two sections of honors Chemistry, and one section of Principles of Technology. He had taught for three years, and was one of four chemistry teachers at his school. He held a Bachelor of Science in chemistry and biology with a license to teach seventh through twelfth grade.

Mr. South taught chemistry in a mid-size city school in the southeastern United States. The school included grades nine through twelve. Based on the 2012-2013 enrollment data the student population was 2,023 students with 72% of the students classified as white. The school had a 90.4% graduation rate with an average ACT score of 19.0. Thirty-two percent of the student population were considered economically disadvantaged and 11% of the students reported having a disability.

Adaptation.

Mr. South used some of the Modeling Instruction curriculum provided to him by the professional development. He explained his use of the curriculum in the following quote, “I started out the beginning of the year Modeling day one, and then throughout a couple weeks we went down to maybe one or two lessons a week. Now, it’s less than that” (Interview South, 2012, November 27). Mr. South adapted the Modeling curriculum by selecting particular lessons rather than implementing a full unit. In addition, Mr. South adopted specific instructional methods from the professional development into his personal strategies for instruction. In his initial interview, he stated, “Granted, I am not using [Modeling Instruction] every day, but I certainly use it as a teaching strategy through every unit” (Interview South, 2012, September 24).

Mr. South used whiteboards in his classroom as a technique from the Modeling Instruction curriculum. He used whiteboards as a way for groups of students to examine specific aspects of a topic.

> For a teacher who’s not using modeling 100% of the day, anytime I see a trend that occurs in my lesson, like when we were talking about frequency versus wavelength, I can bring modeling in and have them draw me scenarios… So, anytime I see a trend, I’m thinking, I’ve got to get the whiteboards out. (Interview South, 2012, September 24)

Investigating mathematical relationships was a common way for Mr. South to implement white boards with his students.

Although he had utilized white boarding sessions, Mr. South indicated that he had difficulty with this in the following quote. “But the hard part is reaching those students who don’t participate in the discussion. So I have to make modifications for them” (Interview South, 2012, September 24). The adaptations that were made by Mr. South to engage students were clarified in the following statement. “After we have a white boarding session, they will have an assignment. Usually it’s not clicking, and I’ll ask them very similar questions that I asked during the whiteboard session” (Interview South, 2012, September 24). Engaging students in group discussion was facilitated by assigning those not participating additional assignments.

Facilitation.

Mr. South used questioning to facilitate student engagement in the topics that were being taught. In the following quote, he described how he would use specific questions as an assessment of the students' prior knowledge.

> I can bring modeling in and have them draw me scenarios. When this happens, what's going to happen here? And it's really having them predict. And then, what kind of background information did they already have, that could help them make those assumptions? (Interview South, 2012, September 24).

Facilitating discussion by questioning was an instructional strategy Mr. South employed when using Modeling. He also explained that after the students collected data he would ask follow up questions. Mr. South routinely asked his students to explain why their data looked like it did and he was frequently surprised at the variety of answers. He stated, "I ask a lot more, 'Why do you think that?' questions. And [the students] hate it because it's not just a blanket answer" (Interview South, 2012, November 27). Mr. South described how he used questioning with his students to encourage critical thinking. He acknowledged the difficulty students had with some questions; however, he also said, "I like to encourage them to even say wrong answers" (Interview South, 2012, November 27). The indication from Mr. South was that he created a culture in which his role was to facilitate student engagement.

During the observation, the researchers noted that Mr. South used a productive talk move in his class called revoicing. When questioned about why he used this strategy for facilitation, he provided the following statement. “That is just a strategy I typically use. A lot of times I’ll do it because students just can’t hear another student say it” (Interview South, 2012, November 27). In this quote, Mr. South explained that he wanted his entire class to receive the information provided by an individual student. Upon further reflection he added the following.

> Another reason is because without telling them they are wrong I can tweak their answer and make it seem like they are right. Chances are they do know what they are talking about. They have little pieces that are right but we can together mold it into the right answer, you know. So they don’t seem like they are wrong. (Interview South, 2012, November 27)

Revoicing was often used as a technique by Mr. South to manipulate student responses into the correct answer.

Facilitating student discussion through wait time was difficult for Mr. South. He admitted that while he wanted students to answer questions, he had difficulty waiting for answers.

> I’m really bad at wait time. I don’t give them enough. And so whenever we’re having a Modeling lesson I really, especially in a 45-minute session, I have to really stop myself. And we end up not doing it as effectively. (Interview South, 2012, November 27)

Modeling lessons were often not completed effectively by Mr. South because students were not allowed time to answer questions. He also demonstrated understanding that the ability to wait for students' responses would increase student engagement.

Pacing.

Mr. South explained that Modeling Instruction was difficult to incorporate because of the time required in class and in preparation. He summarized this sentiment by saying, "We're on a really tight schedule. You know, we have to get so many standards done in six weeks" (Interview South, 2012, September 24). Mr. South indicated that the use of Modeling Instruction curriculum would hinder his ability to complete the content required for his course. He concluded, "Our scope and sequence doesn't allow that kind of time" (Interview South, 2012, November 27).

The time needed for students to construct responses detracted from Mr. South's interest in implement Modeling Instruction.

> I mean, you've got to have the time to wait for their responses. And, even if you're feeding them those leading questions; you want them to do it on their own. And that's hard whenever you have a 45-minute class period. You have so many interruptions in (the) public school setting like testing, or other school events. So, timing was a huge issue. (Interview South, 2012, September 24)

Mr. South stated that the instructional techniques required for implementing Modeling Instruction successfully were difficult to maintain when students were in the reality of a public school classroom. Mr. South explained that when students had longer classes he was able to be more effective.

> With my first period, I have 45-minutes and all of my other classes I have 86-minutes on a block day. Those block days are wonderful. And typically in an 86-minute period I can do a really good modeling lesson. In 45-minutes, not so much. (Interview South, 2012, November 27)

Mr. South was not only concerned with the time that implementing Modeling Instruction required in class, but also with the amount of time required to prepare for lessons.

> When teachers have more than one prep it really eats into the time that they can spend on a Modeling lesson. Right now I have three preps. I'm spread pretty thin on my lesson, so my honors and my standard seem pretty similar. I just make different accommodations. And my Principles of Technology really suffers. I have one class [with] 13 students as opposed to four classes of chemistry with 112." (Interview South, 2012, November 27)

Mr. South explained that because he was teaching three different classes he did not have the time too successfully prepare for Modeling lessons.

Content.

Mr. South discussed the inability of the Modeling Instruction curriculum to address every standard that the students were accountable for learning. The lack of specific timelines and complete content were both contributing factors to Mr. South's decision to not utilize the Modeling curriculum. "We're not able to do a genuine Modeling lesson as frequently as I had imagined. Mainly because it doesn't always align with our scope and sequence" (Interview South, 2012, November 27). In this quote from the final interview, it is clear that Mr. South was concerned that all the topics in the scope and sequence were not found in the Modeling curriculum and that no one had mapped Modeling on to his curriculum. The sentiment was similar in his initial interview; when asked what would assist in implementation of Modeling Instruction Mr. South answered:

> Aligning it with my state standards. The Modeling curriculum does not 100% align with all of my standards. Which is why I am using it in partiality, I mean I am not able to implement it 100%. And I can't go in the same sequence as the Modeling scope and sequence is, because I am held by my district's scope and sequence. (Interview South, 2012, September 24)

Mr. South explained that he used his district's scope and sequence to structure class lessons.

> A scope and sequence that follows our county scope and sequence would be very helpful. Now, and that's the thing, I know [Modeling Instruction] is all building on what [the students] don't know and then you build up, but I think we have a really good scope and sequence. (Interview South, 2012, September 24)

In the previous quote, Mr. South upheld his district scope while he also acknowledged construction of student knowledge being central to the Modeling Instructional design. This misalignment of content was a difficulty for which Mr. South had devised a solution. In the following quote, he indicated that full implementation would be possible if the curriculum were aligned. "Modeling doesn't offer our full scope, like Modeling doesn't actually hit all of our standards. If [Modeling Instruction] were a blanket curriculum than we could implement it from day one to the end of finals" (Interview South, 2012, November 27).

Mr. South gave specific examples of standards that were not addressed in the curriculum materials provided during the professional development.

> Of course there are some standards that are by the state, that are not covered in Modeling. Like nuclear, there are a couple of things. And I haven't looked into electron configuration yet, s, p, d, and f orbitals. That's what we're about to start talking about in a little bit. (Interview South, 2012, September 24)

The lack of a lesson that was predesigned for use with Modeling was noted by Mr. South in the following quote. "I'm going to be winging that one, because I don't know of nuclear Modeling. Especially since there are very few labs as opposed to just, you know particle decay and flipping pennies." (Interview South, 2012, September 24)

The inability of the curriculum to completely address standards was not the only difficulty Mr. South had with the content provided by Modeling Instruction. In the final interview he noted the same content as being not covered, and explained that energy was highlighted too frequently.

> We don't have the full curriculum with Modeling. It doesn't talk about... It talks too much about energy transfer, when that is one of our standards. As opposed to

> all of our other standards that we would need to spend more time on. (Interview South, 2012, November 27)

Modeling Instruction used energy diagrams in most units to demonstrate the changes that occurred during various chemical processes. Energy transfer was one of many standards that Mr. South was responsible for teaching, and he indicated that a lot of emphasis was on one part of the content. Additionally, nomenclature was part of the Modeling Instruction curriculum that Mr. South found ineffective. He stated, "Some of the units, like with naming compounds I can see the benefit of it, but at the same time it is a lot of rote memorization. So the exploration is not – I don't think as effective" (Interview South, 2012, November 27). In this instance, Mr. South's opinion was that Modeling Instruction was not the most effective way for students to be presented content.

Student Understanding.

Mr. South cited enhanced student conceptual understanding as a change that occurred in his class resulting from the professional development. "Whenever I do Modeling, it helps them (the students) develop their own concepts" (Interview South, 2012, September 24). He described this development of conceptual understandings in the following quote. "The students were able to accurately describe, in their own words, what was happening" (Interview South, 2012, September 24). Mr. South noted that the ability of students to provide evidence and explanations for demonstrations and laboratories as being strength of Modeling.

> So, I know the ideal lesson is to let them discover the trend. But in all actuality, if they can't discover the trend on their own by the end of class, I've got to give it to them and help walk them through why that's the trend." (Interview South, 2012, September 24)

Once again, despite the advantages Mr. South saw in the Modeling curriculum, time constraints continued to be first and foremost in Mr. South's concerns.

Student Participation.

Mr. South encouraged classroom participation through the use of Modeling Instruction techniques. When asked how the techniques worked in the classroom he stated, "The students respond to it. [The students] like it because they're not having to do as much book-work. It's a lot of discussion" (Interview South, 2012, September 24). Mr. South elaborated on the in-class discussions by describing the interactions.

> They kept on critiquing each other, "No, no, that's not why that happens." "I mean, that would have happened if that was the case." And they were actually able to provide evidence. And, I don't think they're used to doing that—at least not in the lab setting" (Interview South, 2012, September 24).

The ability for students to engage in one-on-one interactions was encouraged by Mr. South. He said, "I like that I don't want it to be just me talking. It's just so boring" (Interview South, 2012, November 27).

Mr. South found that he initially had problems with student participation, "but the hard part is reaching those students who don't participate in the discussion" (Interview

South, 2012, September 24). The adaptations that he made to increase participation included questions that the student would have to answer individually. He found that:

> If there's an assignment attached to it (a Modeling session), they're much more likely to discuss in their groups, "Hey, what are you getting over there?" "Ok, why's that?" And then we'll have a group discussion based on [the students'] answers from their small groups. (Interview South, 2012, September 24).

The student interaction during class underwent a transformation as the semester continued. Mr. South summarized this transformation in the following quote:

> They like talking to each other. They are a little bit awkward at first because they don't know how to talk to each other politely and criticize each other um, but my students have no problem talking to somebody on the other side of the room, now. (Interview South, 2012, November 27)

The ability for students to comfortably interact with one another was a benefit, cited by Mr. South, to his classroom environment.

Student Ability.

The ability of his students to think critically was something that Mr. South acknowledged as a skill his students struggled with or lacked. "I can tell that my students don't know how to think" (Interview South, 2012, September 24). Mr. South stated that during Modeling Instruction discussions there were "some students I lose and I don't get them back" (Interview South, 2012, September 24). When he was asked to elaborate, he said.

> They're not used to thinking. They're not used to being held accountable, for their own original thought. So right now, they're certainly not used to it. I mean, we're only six weeks in. So they're still developing that. Which is why I'm helping them with their answers" (Interview South, 2012, September 24).

In the previous quote, Mr. South explained that his students needed help in the ability to develop accountability for original thoughts. Alternatively, he stated that student ability to work with the technological equipment for analysis was easy. "I brought in the laptops and they could see how it translated. And it was so much easier for them because they're tech savvy. And, they just popped in that line. And they're like, 'Well, there's my slope!'" (Interview South, 2012, September 24).

Mr. South indicated that there was a difference in ability between his honors students and standard students.

> I don't know if my standard students would be able to sit around at a board meeting and explain. 'Well, why did you write it that way?' 'Um, well I don't know' I think I would get a lot of that. My honors students are a little bit different. They'll go for it and they'll kinda play the game so to speak. (Interview South, 2012, November 27)

Mr. South suggested that instruction should be further differentiated for students.

> Some kids belong in a lecture-based class, some kids don't. I think that is another problem, is that you have to differentiate so much within one class. It would be

> great if we could say, "You're going to do Modeling sign up for Modeling. You're going to do lecture based." (Interview South, 2012, November 27)

Student ability to think critically and the differentiation of instruction were both factors that impacted Modeling Instruction implementation for Mr. South.

Social.

Mr. South had a community of coworkers that also participated in the Modeling Instruction professional development. He explained the feedback from his coworkers in the following quote.

> We have four people in our chemistry department. Two of which are trained on Modeling. One did not go to the Modeling session and one is a brand new teacher this year. So, that brand new teacher is just trying to float, you know. And the teacher that did not go to Modeling - she doesn't see it as a completely new way. [Modeling Instruction is] just one of those, "If I have time, I might model." So, they think it's good. But it's, implementing it is not as easy. (Interview South, 2012, September 24)

Mr. South clarified that some of the difficulty of implementation of Modeling Instruction was the lack of training for teachers that did not attend the professional development.

> I offer my whiteboards for them to borrow and use in their sessions. But it's really learning how to question your students that, that's what the workshop helped me do, is learn what questions do I need to ask. So that's the thing they're lacking if they didn't do the workshop. (Interview South, 2012, September 24)

Although, Mr. South cited the ability to use questioning effectively, the inability of his coworkers to “know what questions to ask” was not his primary social barrier to implementation.

As previously stated pacing and content were both implementation barriers for Mr. South. He explained that his peers had similar concerns. “Coworkers seem to agree that Modeling does not fit our scope and that we are already pressed for time on the standards we do have.” (Interview South, 2012, November 27) When the researcher asked what Mr. South thought would occur if the alignment were in place, he responded, “I think it would be more effective, and I think that administration would be more likely to make it a specific Modeling course, as opposed to just here’s a Modeling strategy that you use in any chemistry class” (Interview South, 2012,November 27).

Mr. South had introduced the topic of a class that specifically used the Modeling Instruction curriculum to the administration after attending the professional development. He explained,

> Administration, they don’t really hear about it anymore. At the beginning of the year I had talked to them about it, and they’re like, “Well we can’t really gear a class towards that right now. We can’t build one in.” (Interview South, 2012, November 27)

Mr. South stated at the conclusion of his interview, “We just we need our higher ups to get behind this” (Interview South, 2012, November 27). Mr. South indicated that implementation of Modeling Instruction was hindered by his administration.

Instructional.

The instructional practices that Mr. South employed in his classroom were cited as being changed, at least initially. Mr. South explained that he started the year using the Modeling lessons we participated in during the professional development. The Modeling lesson that Mr. South described using in his class was the introductory lesson of the professional development. He explained his student reaction to the lesson in the following statement.

> The can explosion demo- They absolutely loved it. [The students] did not expect it to light on the top and then also, they didn't know. Most of them thought it would explode but then once the flame looked like it went out they just kinda gave up and kept writing. And then it exploded, so that was a great experience." (Interview South, 2012, September 24)

In this demonstration, the students were introduced to an instructional environment that Mr. South had been trained in at the workshop for Modeling Instruction curriculum. Mr. South further explained his implementation in the following quote.

> We did some of the Modeling approach to determine, what does the slope actually MEAN for that. It was the density lab. So I would say the white boarding sessions; we are implementing those anytime there's a trend. And using technology in my lab as far as the computers are concerned, so they can see trends. (Interview South, 2012, September 24)

In the density lab Mr. South referred to in the previous quote, students explored the relationship between the mass and volume of substances to obtain a model for density.

Mr. South explained that the laptops and virtual representation of the physical relationships, which were a part of the Modeling Instruction curriculum, were implemented because they appeared to support the development of student understanding.

> Any sort of relationship, and also, I'm bringing in the laptops now, in my lab and they loved it. Because we did, my first lab they hand-graphed everything, now, granted, they don't know how to hand-graph either. But, then I brought in the laptops and they could see how it translated, and it was so much easier for them" (Interview South, 2012, September 24).

Mr. South identified the following difficulty when using whiteboards as an instructional tool.

> Leaving up white boards long enough to go through the rest of the day so we can revisit what they drew, well you need more white boards. You need white boards that don't stain if the markers are on there for longer than 24 hours. Which, nobody could have predicted that. (Interview South, 2012, November 27)

The instructional changes that Mr. South implemented were hindered by the inability to allow student work to remain on the whiteboards for more than one class period. Mr. South suggested additional or higher quality supplies.

***RTOP*.**

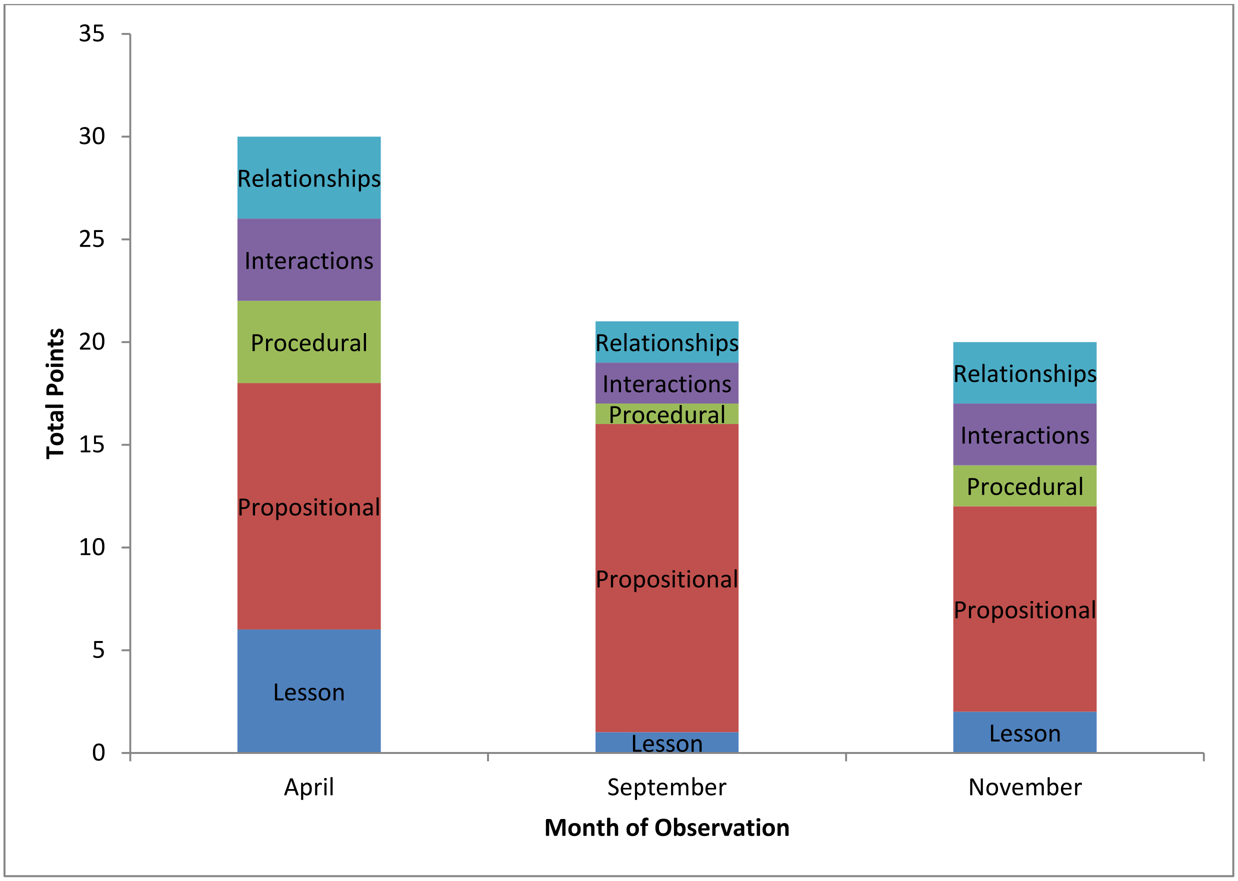

Figure 4. Mr. South scores from each RTOP divided into five categories. From bottom to top: lesson design and implementation, propositional content knowledge, procedural content knowledge, communicative interactions, and student teacher relationship.

The RTOP scores for Mr. South, as shown in Figure 4, indicated that his classroom was less student-centered after the professional development. The greatest difference in score was reported by Observers' J and Q in the category of lesson design and implementation. Further analysis of the Field Notes revealed that the lesson was more student-centered in Mr. Souths' classroom when new content was not being presented. The structure of the review lesson also helped to explain the fluctuation noted in content knowledge. The Field Notes recorded by the observers were further analyzed to clarify the changes in the lesson, propositional, and procedural content knowledge sections of Figure 2.

Lesson design and implementation.

Mr. South had the most change of score in the lesson design and implementation section of the RTOP. In this section, Mr. South received his highest score for the initial observation lesson, which was a review session. Mr. South used instructional strategies in this section that engaged students in content-focused conversation. For example in the following excerpt from observation field notes, Observer Q noted Mr. Souths' use of a review sheet to guide informal assessments. "[Mr. South] started going over review sheets… [While going over answers] the teacher questioned students about balancing equations" (Field Notes, Observer Q, 2012, April 26). In response Mr. South shifted the direction of the lesson to allow students' ideas to be addressed. Observer J wrote, "The students had different answers [to one of the questions Mr. South asked]. He used the student responses to create a question with multiple answers" (Field Notes, Observer J, 2012, April 26). The students were asked to identify which answer was correct as Observer Q explained, "[he] took a poll" (Field Notes, Observer Q, 2012, April 26). The previous notes indicated that Mr. South was observed using a variety of instructional strategies that stimulated student engagement during his initial observation. The lesson was concluded with a review game that encouraged students to assist one another in developing content knowledge. Observer Q described the game in the following statements. “[Mr. South] started a game, called the hot spot review. [The students in] class described a term to [a] student in [the] front [of the room] who cannot see [the chemistry term], without using any part of the word” (Field Notes, Observer Q, 2012, April 26). The lesson design allowed students to explain their knowledge as part of a learning community which is an important component of the RTOP section lesson design and implementation. This lesson structure was not used in subsequent observations, as each time Mr. South was observed he used a different lesson structure.

In the lesson design and implementation category, Mr. South received lower scores on both of the follow-up observation lessons. In both lessons Mr. South presented introductory content to the students. The instructional strategies that Mr. South used included presenting information with Power Point slides and, in the final observation, worksheets. In the September observation, Mr. Souths’ lesson required students to take notes by filling in workbooks while he presented information. “[The] teacher asks students to get out workbooks ‘Continue to develop our model of the atom.’ He is lecturing from notes on PowerPoints” (Field Notes, Observer Q, 2012, September 24). Observer Q noted that Mr. South provided an opportunity for students to physically interact with the content in the following example. “Has students stand up and make wave motions, large wavelength small frequency, etc." (Field Notes, Observer Q, 2012, September 24). The previous excerpt described how Mr. South's lesson, engaged students as members of a learning community, a key aspect of the lesson design and implementation section of the RTOP, through the synchronizing of content and movement it promoted.

The following observation offers an example of the lesson implementation that Mr. South used to encourage his students to complete the worksheet prior to the presentation of correct answers. "Unless you struggle with this it won't help you. Take four minutes to work as hard as you can to get some done" (Field Notes, Observer Q, 2012, November 27). In the following excerpts Observer Q captured Mr. Souths' continued use of worksheets.

> Worksheet and answers on the board, just page one. Teacher asks how many students did not finish…teacher turns off answers on board…Continuing with worksheets – asking questions, low order, to work students through answers… Puts answers up. Gives students time to check their answers… Passes out worksheet. Goes over directions – gives them ten minutes to work on it." (Field Notes, Observer Q, 2012, November 27)

The previous excerpt showed Mr. Souths' attempt to encourage student engagement in chemistry content, for this lesson students were expected to complete their worksheets individually. Observer J noted that Mr. South told his students to interact with one another, "Four minutes to work on the sheet, or check answers with another student.

Teacher walked around class" (Field Notes, Observer J, 2012, November 27). The lesson design in this instance did not allow for further student-to-student communication, an aspect of the RTOP category lesson design and implementation.

Content.

The overall content score that Mr. South earned was the same from April to September although the distribution between propositional and procedural changed. Mr. South had a higher score for propositional in September. The final observation revealed an overall decrease to propositional knowledge with little change in procedural knowledge. Descriptions from the knowledge categories follow.

Propositional knowledge.

Each lesson that was observed included content fundamental to chemistry. During the initial lesson, Mr. South demonstrated his grasp of the subject matter while he assisted students in the development of understanding. Observer J noted that, "[Mr. South] further explained what students were confused about" (Field Notes, Observer J, 2012, April 26). The chemistry knowledge that was displayed by Mr. South during his explanation indicated that he understood the content well enough to ascertain the difficulty his students' were experiencing. Mr. South demonstrated, during the initial observation lesson, his understanding of content as well as the ability to tie content to real world events and other disciplines - key aspects of the propositional content knowledge category of the RTOP. In the following excerpt Mr. South was noted connecting mathematics to chemistry during his instruction, "The teacher used a mathematics comparison to a triangle" (Field Notes, Observer J, 2012, April 26). Mr. South also connected content to real world events during the initial observation lesson. Observer Q noted, "[Mr. South] talked about the Japan nuclear disaster, situation, when talking about control rods/reactions" (Field Notes, Observer Q, 2012, April 26).

The increase of propositional knowledge from the initial observation to the post observation was noted in several incidents during Mr. South's observed lesson. The noted increase was partially attributed to the fact that Mr. South presented content for the first time to students, rather than reviewed. The conceptual connections were made explicitly, and real world connections continued to be observed in September. "[Mr. South] talks about different types of waves, [and] relates them to a real-life story about his cat being affected by high frequency sounds" (Field Notes, Observer Q, 2012, September 24). Mr. South further displayed his propositional knowledge in the following excerpt from Observer J. "[Mr. South noted that] inverse and direct relationships [occurred in chemistry just like in math]. [He] has students stand up – put hand straight up demonstrates wavelength with arms. [Mr. South] explained that large wavelengths [have a] small frequency, etc." (Field Notes, Observer J, 2012, September 24). The previous statement noted that Mr. South demonstrated a concrete example, arm movement, to represent the abstract concept of energy waves.

The decrease in propositional knowledge, observed between September and November, occurred when Mr. South used a lesson that presented answers to students after they worked in class. During this lesson Mr. South used terminology from mathematics when he explained ionic chemical formulas. Observer Q noted, “[Mr. South] discussed distributive property of math when explaining $Mg_3(PO_4)_2$”(Field Notes, Observer Q, 2012, November 27). After the worksheets were completed Mr. South changed topics. As noted by Observer Q, “Teacher begins lecturing about molar mass” (Field Notes, Observer Q, 2012, November 27). The change of topics and lack of real world connections attributed to Mr. Souths’ decreased score in propositional knowledge.

Procedural knowledge.

Mr. South engaged students in some classroom activities that facilitated their involvement in chemistry content, as required in the procedural content knowledge section of the RTOP. Mr. South received his highest procedural score from the initial observation. During the initial observation Mr. South involved students in communicating their understanding. “[Students were] working problems on [the] board” (Field Notes, Observer Q, 2012, April 26). Mr. South also encouraged students to be reflective in their learning as Observer J noted, “Student asked to explain their answer” (Field Notes, Observer J, 2012, April 26).

Mr. South presented his second observed lesson with a series of PowerPoint slides. The behavior Mr. South expected from his students was noted in the following quote. “Class quite – copy this down please” (Field Notes, Observer J, 2012, September 24). In the previous example Mr. South engaged students through writing, but discussion was not encouraged. Mr. South received his lowest score in procedural knowledge in

September, as the RTOP category of procedural content knowledge focuses on the students' involvement.

During the final observation Observer Q noted, Mr. South was "showing students how to write answers, but not really explaining the concept. [Student] How did you know that?' Answer – it's on the chart. Eventually explains concept behind the technique he is teaching" (Field Notes, Observer Q, 2012, November 27). In the previous quote Observer Q noted a delayed conceptual explanation for the content that Mr. South was presenting. Observer Q later noted that Mr. South encouraged his students to reflect on their work and determine where difficulties could arise. "What do you think the most common mistakes are? [Mr. South] generates a list on the board using student suggestions, and his own ideas" (Field Notes, Observer Q, 2012, November 27) Mr. South allowed his students to participate in discussion about their difficulty with the subject matter in a constructive manner which is what accounted for the slight increase to his procedural content knowledge score.

Ms. East.

Background.

Ms. East was a Caucasian female in her forties. At the time of the study, she was teaching standard and inclusion Chemistry. Ms. East was in a chemistry department that had four other teachers. Ms. East held teaching certifications in mathematics for kindergarten through twelve, and science seven through twelve. She had been teaching for 19 years.

Ms. East taught chemistry in a mid-size city school in the southeastern United States. The school included grades nine through twelve. The statistics for the 2012-2013 school year listed the student population at 2382 students with 76% of the students as white. The school had a 93.6% graduation rate with an average ACT score of 20.7. The student population contained 25.4% that were considered economically disadvantaged and 9.2% of students reported having a disability.

Adaptation.

Ms. East stated that she initially used the instructional material provided to her at the professional development. Although, she admitted that alterations were needed for her students. “I’ll tell you this after doing it for a year I’m going to change a bunch of stuff. We’re making notes as we go through…We’re finding out, there’s things very quickly that we found out we had to modify to adjust for our kids” (Interview East, 2012, September 18). Ms. East explained that she gave the students information about their expected results in the following statement. “Now with this class I went over it at the beginning more foreshadowing of what they were supposed to get out of it" (Interview East, 2012, September 18). Modeling lessons presented according to the instructions from the professional development required students to evaluate the data they collected and construct a model based on evidence.

At the time of the second interview Ms. East had further adapted the Modeling curriculum. "We're not following the format the way it was initially. We broke it out and started going back to our text book format a little bit" (Interview, East, 2012, November 28). Ms. East further explained her approach in the following statement.

> I presented information to the group and then we did a lot of individual working with them. I have an educational assistant. So one to five is the ratio of this class, between the educational assistant and myself. With the level of students in this class we do much better one on one than we do as a group. (Interview, East, 2012, November 28)

Ms. East adapted her instruction from group to individual, and used some of the textbook structure to inform lesson design. Ms. East noted utilizing some of the instructional material, worksheets mostly, provided to her at the professional development.

Facilitation.

Ms. East explained that she tried to facilitate student discourse that encouraged the construction of knowledge, and experienced difficulty. Ms. East said, "I try very, very hard to let them figure it out" (Interview East, 2012, September 18). She assisted the students with "foreshadowing" and explained, "If I had not done that there would have been so much blank I don't know what I'm doing" (Interview East, 2012, September 18). Conversation between students to create understanding was not a part of the classroom learning environment that Ms. East encouraged, because the students were told what to expect in advance.

Facilitation of student interactions was an area that Ms. East struggled with during her attempted implementation of Modeling Instruction. She stated,

> You can literally answer the same question multiple times in a row, and yes sometimes it's just that sixteen or seventeen year old, teenager I'm not listening to you. But... We will work with them and we will do five problems right in a row. And they're just getting them *snapping* pow pow pow pow pow. [The students] understand it they know what they are doing. You can come back the next day and it will be like they have never seen that before. That processing, and then the other thing that is very, very hard for lots of these kids is they have no feel for numbers what so ever. (Interview East, 2012, September 18)

Ms. East experienced further difficulty, as stated in the following quote, in facilitating the building of collaborative classroom knowledge, because her students did not have a conceptual understanding of numerical values.

> They were getting answers when they were putting stuff into the calculator wrong of a thickness of .5 a half centimeter seemed reasonable to them. You know, that's when I was trying to get them to hold up and look. "What does this piece of aluminum foil look like? How thick is this?" and then I would hold up that same

> you know whatever answer they had on the on that ruler. "Does this look the same?" you know "Are you seeing the same?" They can sit there and tell you no, but when they saw that number in the calculator it was a perfectly valid number to them. Because the calculator said it, so it must be right. (Interview East, 2012, September 18)

In the previous example Ms. East described the type of questions that she used in her classroom The nature of the questions Ms. East asked limited the amount of discussion students were allowed, because they were mostly answered correctly with either a short answer.

Ms. East noted appreciation for the follow-up workshop because of the focus on productive talk moves. "My favorite part of the follow-up workshop was the different ways to get the kids to respond, to get them on cue and keep them talking and answering and stuff" (Interview, East, 2012, November 28). Ms. East explained that she used one type of facilitation, but found changing her strategies difficult. "Cause I've always done revoicing. I am a creature of habit. It's really hard not to break. If you have a certain teaching style to change that teaching style is really hard" (Interview, East, 2012, November 28). Although Ms. East appreciated the instruction on facilitation, she continued to struggle with implementation.

Pacing.

Continued implementation of Modeling Instruction was made more difficult for Ms. East because she was unaware of the time that should be allowed for each lesson.

Ms. East emphasized her need for a curriculum that had a structured timeline during the first interview. “Early on, all I need to know how far off am I, on pacing? That is a very important question I have” (Interview East, 2012, September 18). She explained her need further in the following quote. “I don’t feel like I have, like normally I know. Okay I should have covered this by now. I should be here by now, and I don’t cause really right now I feel like I haven’t taught any chemistry” (Interview East, 2012, September 18). At the time of the initial interview Ms. East was working on density in her class. The pace at which the content was being taught contributed to Ms. East adopting to use her previous curriculum. “We broke it out and started going back to our text book format a little bit to try and speed up some of our rate” (Interview, East, 2012, November 28). Ultimately Ms. East discontinued use of the Modeling Instruction curriculum. “It is that order that was getting us, of teaching it. And maybe that’s just, not being as you know - old dog new trick. It’s hard to teach us” (Interview, East, 2012, November 28). Ms. East indicated that the curriculum order and the lack of a pacing guide were both factors that contributed to her inability to effectively implement Modeling Instruction.

Content.

The content that was being covered in the first unit of Modeling Instruction was noted by Ms. East as not feeling like chemistry, she also indicated that the abstract nature of chemistry contributed to her difficulty with implementation. “I’ve covered some concepts and stuff, but I haven’t really taught anything directly off my main check list of what’s in Chemistry 101 or whatever” (Interview, East, 2012, September 18). Although

Ms. East noted that the content students' received in her class was not evaluated she elected to discontinue her implementation of the curriculum.

> No one is ever going to come beat me up for not covering X amount of information this year in chemistry is what I am saying. They're [her students] not going to take AP chemistry next year and not have the basics. And they're not going to go you know…So and I don't have an EOC class, so I'm not going to get yelled at by the state. So no one is ever really going to know that I don't cover certain information. But that I find to be my biggest weakness with this [Modeling Instruction] is I don't feel like I have. Like normally I know ok I should have covered this by now I should be here by now and I don't cause really right now I feel like I haven't taught any chemistry. (Interview, East, 2012, September 18)

Ms. East further explained some of her thoughts about the content of chemistry in the following quote.

> So much of chemistry, all of chemistry really, is occurring at beyond their vision level. So you're doing, and I like the idea of the particle drawings I've tried to get them to think what's happening. But they [the students] can't see it and even when we talk about it and stuff - they can't see it. And kids are, before you get that higher order thinking skills you're a, you're a concrete learner just like you were when you were a baby. You know if it was hot, it was hot. If you dropped it, it went down. It went down. You know you had to see what happened and I think that is still very, very hard to achieve in chemistry. Even trying to utilize the

> particle drawings, even trying to do the labs and things that are trying to bring it up to a tangible scale; get real, you haven't touched chemistry yet" (Interview East, 2012, September 18).

Ms. East felt that the abstract nature of the chemistry concepts made Modeling Instruction difficult as compared to physical sciences, she stated. "PT [Principles of Technology] is very much geared toward modeling…I find chemistry harder to do with it then I did the physics" (Interview, East, 2012, September 18). Ms. East explained that the students' grades were a contributing factor to her desire to change the order in which content was presented. "No child should be left behind, so that's the reason that we changed our order. I think if we had gone into that concept with the energies and the heat and stuff. I think we would have, I think they just, I cannot imagine the drop rate we would have had at Christmas" (Interview, East, 2012, November 28). The content that was presented instead was selected because Ms. East assumed the students' would perform better. "We just, we were looking for a section to cover next that would boost confidence and grades" (Interview, East, 2012, November 28). While Ms. East agreed that particle drawings were a good tool for content she ultimately decided that the Modeling Instruction curriculum did not cover what she viewed as chemistry content.

Student Understanding.

The previous sections have alluded to the difficulties that Ms. East had with her students' ability to construct an understanding by using the Modeling Instruction curriculum. She explained her need for a change of curriculum in the following quote.

> We did not think our kids would follow. We thought we would lose them [the students], because we had done a little bit of math with conversions, and almost lost them. Because they were failing so royally at math, we had to come back, and come up with something. (Interview, East, 2012, November 28)

The difficulty with students' understanding of mathematics was noted by Ms. East in the initial interview. "They need more math practice than what we were initially thinking" (Interview East, 2012, September 18).

Ms. East had used a curriculum that employed instructional strategies that were similar to Modeling Instruction when she had taught Principles of Technology (PT). She expressed unease about the students being able to gain conceptual understanding. "A concern I have is, when do I hit that point where that little light bulb starts to go off for them [the students]?"(Interview, East, 2012, September 18). She explained further,

> I have this feeling that at some point it's going to come together because that's the way PT always was. I felt like I spent the entire first semester of PT training them to think. And then second semester I always said I didn't even have to teach, because by then I had trained them to think and they started thinking for themselves. They started to just, I would present stuff out there and they would start sucking it in, and figuring out how it worked. And applying the stuff they already knew. And that's what I feel like theoretically is supposed to happen with this [Modeling Instruction]. I'm a little concerned whether I am going to hit that point. *laughter* Or if I hit that point early enough to see any reaping of the

> benefits…My PT kids used to do that they would hit somewhere about second semester. And they would look at me and they'd go, you're really not teaching us stuff anymore are you? *laughter* The smart ones they'd sit back there and go wait a minute you're spending a lot more time just sitting behind your desk now aren't you?... You know and they would figure out, and I would say, but yeah look how much stuff you're learning now. And they're like well yeah, because I know a lot of stuff now. You know they're like, and when they get that ownership kids will, humans in general will do that. Once you have ownership of you knowledge of your ability to educate yourself your wow. Then you're on your own. (Interview, East, 2012, September 18)

Although Ms. East acknowledged the benefits of student constructed understanding she was not confident enough in her implementation of the Modeling Instruction curriculum to continue.

Student Participation.

The difficulties that Ms. East experienced in facilitating group activities in Modeling Instruction caused her to not implement instructional strategies from the curriculum that encouraged student participation in discourse about chemistry content.

Student Ability.

Student ability was a large factor in Ms. East's ability to implement Modeling Instruction effectively. She noted a difference in the student ability when describing how her students had changed from the previous year.

> This is the year that they have to have chemistry. So are my students different in this year than last year? Yes, because I have kids who are very low compared to what I have had in the past. So are my students different this year? Yes. Are they different because of Modeling? No. They are different because of a state graduation requirement, because these kids are the ones that can't graduate without Chemistry or Physics…I have kids who are seniors, who are just now getting around to taking Chemistry. Because they couldn't pass Algebra one until just last year as a junior, and that is your prerequisite for Chemistry is Algebra one…I've got these kids that were not on track and here they're sitting as seniors now. So they're, they are the lowest academic level there is. (Interview, East, 2012, November 28)

Ms. East noted students' ability when she talked about the observed lesson during the interview. "This is an inclusion class seventy percent of those kids have pretty extreme modifications. Most of them have a severe enough learning disability that they don't retain it [content presented previously]" (Interview, East, 2012, September 18). The inability for her students it understand content was only one of the reasons student ability impacted Modeling Instruction implementation for Ms. East.

> I have a fairly big discrepancy in student skill. And I think that I am losing the upper end cause they're getting bored, and I think that I am losing the really, really lower end, because no fault of the Modeling. I just think that I am losing the

> lower end. I think Chemistry is just beyond their scope. (Interview, East, 2012, September 18)

Ms. East noted that students' age impacted their ability to conceptualize chemistry. "Some kids, are just simply immature. That hadn't grown up yet; they may wake up when they're twenty" (Interview, East, 2012, September 18). Student ability was a contributing factor for Ms. East's implementation in that she did not feel that the instructional techniques employed were applicable to all students.

> I think it depends on the kid. I have kids who if I tried doing this with them would just snap. They would go tell me, give me the book. And they would go read the book and learn the book instead of sitting through this [Modeling Instruction]. I have kids who if you gave them the book they were going to read, and they couldn't get anything out of it at all" (Interview, East, 2012, September 18).

The implementation of Modeling Instruction for Ms. East was hindered by student ability. The techniques employed by the curriculum were not compatible with the needs of her students.

Social.

The social factors that impacted Ms. East's implementation of Modeling Instruction were related to her peers rather than her administration. When asked about thoughts her administration shared Ms. East replied.

> Administration, they don't even know we are really doing it I don't think. *laughter* That's okay, that's not a bad thing. We have a new principle this year

> so he's just kinda making do. I don't mean that ugly I mean he just…it's all new. He came from a small school so it's very different for him. And traditionally the policy at this high school was as long as you were doing your job no body was ever going to come tell you how to do it…I have an administration who's always left me alone because they know. I knew what I was doing. And that I take care of it I don't have discipline problems, even if I have kids that are bad. I don't have discipline problems cause I know how to deal with them. I just, I'm either very blessed in that my administration really does leave me alone whether I am good or bad. Or I've been good enough that my administration leaves me alone and they know that I know what I am doing. I don't know which one it is I would like to think it's the later. (Interview, East, 2012, September 18)

When asked again after the final observation Ms. East responded about administration similarly.

> Not from my administration – they are clueless. I mean if I said Modeling I am not sure if they would know what I was talking about. My coworkers we've talked amongst ourselves. As far as well, you know Ms. West and me. I mean, we're constant. Ms. West and I are team teaching, so we've discussed. We like a lot of the labs and a lot of activities that are in the Modeling. (Interview, East, 2012, November 28)

Ms. East discussed her other coworkers in greater detail during the initial interview.

> We actually started off trying to do all of us that teach [using Modeling Instruction curriculum]. There's five of us that teach Chemistry. We were all trying to do it even though we had the advanced honors on down. Three of us had been to the workshop. Me, Ms. West and Ms. Central have all been, we were there [at the professional development this summer. (Interview, East, 2012, September 18)

The attempted implementation was no longer in place by the time of the initial interview.

> My other teacher [Ms. Central], who actually went through the Modeling [professional development], she is kind of bagging it [Modeling Instruction]. She says she feels like she's just going to be too far behind on what we're supposed to get covered. (Interview, East, 2012, September 18)

Ms. East further explained that the one teacher that had not participated in the summer professional development had previous training, but discontinued implementation because of time constraints.

> She [Ms. Down] had that Modeling experience; she did not have the chemistry (professional development). Because that gives her three preps the chemistry does, she's got AP physics, physics and standard chemistry…It's very hard to get a third prep especially when you are doing an AP class, because AP class will eat you alive. (Interview, East, 2012, September 18)

Ms. East revealed that the implementation of Modeling Instruction was unsuccessful for the last teacher as well.

> The other teacher [Mr. Up] has advanced honors. [He] had no background with the Modeling. [He] was willing to try some of it, but said he did not feel like it was suited for the level of student he had… all of his kids are college bound. Like high level college bound kids, and he wants them to know everything they need to know in the way, the way they are going to have to do it when they get to college, which is basically lecture…Ninety percent of it's still lecture. (Interview, East, 2012, September 18)

Ms. East described her thoughts on student preparation for university level Chemistry in the following quote.

> I think that they should be prepared for lecture, I think they better be prepared for what I had which was [writing] on the board. [Professor] went up to the board didn't come back down. It was presented, presented, presented, and you better know it. Also I will tell you this, the biggest thing they need to learn how to do is learn. How to learn on their own, and I think we have spoon feed them [students']. (Interview, East, 2012, September 18).

Ms. East had previously expressed an understanding of the potential ability for Modeling Instruction to increase student learning. When questioned about which method would prepare students' best for learning Ms. East replied, "Do you change the universities and then change us to match the universities? Or do you change us to match the universities? Or do you change us and then try to change the universities to match up?" (Interview, East, 2012, September 18).

Ultimately Ms. East decided, “I think it’s a toss-up. I think you are talking 50:50” (Interview, East, 2012, September 18). The implementation of Modeling Instruction was not viewed as a priority to Ms. East, because the techniques used in the curriculum were not familiar to her, or her peers. In her experience of lecture instruction the responsibility for learning was on the student, the instructional strategies needed for Modeling Instruction were not valued.

Instructional.

Ms. East originally stated that her instruction had changed because of the professional development although by November she no longer noted a change to instructional techniques. Initially Ms. East said her instruction had changed “completely. I’m going in a completely different order than before. I would have told the kids what to do by now” (Interview, East, 2012, September 18). When asked about her instructional changes in November Ms. East said, “Not a lot. I try to be more geared for more hands on activities and things and stuff, probably. But I would not say I have done a major change, in what I would have done in the past” (Interview, East, 2012, November 28). Ms. East initially thought that the instructional strategies she used were similar to what was needed for Modeling Instruction.

> We didn’t know what we were doing, but what I taught, what I saw from the workshop this summer, I was doing Modeling. Matter of fact some of the stuff I do…was like, I was sitting there going yup I already do stuff like that. That’s what I do. ” (Interview, East, 2012, September 18)

Ms. East stated, “I didn’t find it that big of a jump” (Interview, East, 2012, September 18). After working on implementing the curriculum Ms. East noted differences. “I just don’t think it’s as effective or as easily applicable as it was. Like I said a lot of the physics… Just common sense as a teacher told me that was a good way to do it [Modeling Instruction]” (Interview, East, 2012, September 18). She followed up by saying,

> I mean the physics part [is] very concrete, very easy to see. So the Modeling for it would be much easier, for physics, then it would be for chemistry. So the concept of Modeling I’m not against, and I’m not against using it for the chemistry. (Interview, East, 2012, September 18).

Ms. East did not discover that implementation of Modeling Instruction curriculum was difficult until she tried to use the techniques in her classroom.

> You don’t know something until you do it. You can sit there and be told something all day long, but until you actually do it whether you process it, or do it, or work with it again, or whatever. You have to have some type of repetition of it before you know it. Most people, there are a few geniuses out there who read something one time and then they’ve got it committed, but and. It [Modeling Instruction] was too much stuff and not enough time to practice it [the instructional techniques]. And as we get further and further away from it [the professional development]. It [instructional technique] is harder to remember. (Interview, East, 2012, November 28)

Ms. East explained that the instructional strategies were unfamiliar and as difficult to implement for her as wrap-up. Ms. East used the following example to explain.

> I keep reminding myself, oh I have to do a wrap up, be sure I do a wrap up. I'm terrible at it, because I never did it and it's so hard. Even though you consciously know you are supposed to be having something that you are supposed to be doing. Changing a habit, it's hard. It's like recrossing your arms. (Interview, East, 2012, November 28)

Ms. East intended to implement the new instructional techniques. She explained, "I wanted to post those little strategies. You all gave us that one page that was like a … So it becomes more of a habit, in my day" (Interview, East, 2012, November 28).

Ms. East explained how she believed a professional development could be adapted to increase her ability to effectively implement the instructional strategies.

> Probably additional training, probably going through more - I felt like we covered the first part pretty good. It was a saturation issue this summer, like so much in such a brief amount of time and no time to go back and practice what you had just gotten. And so instead of one huge giant bite, it would have been better to have it [the Modeling Instruction curriculum] broken down. Here's first semester, here's first quarter break it into quarter chunks, and then gone back and been exposed to the curriculum for the next quarter and stuff. So much and no time to implement what you've gotten. I mean right now can you remember what all we did? Cause it's too much. And then it gets to be six months ago and you didn't practice what

> it was right away. Like when we first came back, the beginning of August. It was easy to do what we had done a month ago, but then as you are getting further and further away from when you had it [the professional development]. It's harder to remember. Because we were looking at something the other day going, "I don't think we did this lab, Did we do this lab? I don't remember doing this lab. We didn't do anything like this. How did we do this?" You know, and then we were talking about order and some of the conductivity things. And Ms. West was like "I don't even remember what those look like", and I was like, "Oh I do, I do they were from Flinn, and we were trying to order those and stuff. But you know the further, it's too much information, and too big of a time span in between your implementation of it to have ownership. (Interview, East, 2012, November 28)

In this quote Ms. East admitted that the techniques presented in the summer were not implemented because she could not recall the information. She continued to explain how the professional development could be adapted to increase familiarity with the instructional techniques necessary for effective implementation.

> It would have to be Saturdays, where you would have to commit a Saturday once a month or whatever, and I would say probably a Saturday. Because we did it in ten, really we did it in nine days. If you took out the fluff, we did it in nine days. So if you did three days during the summer, four days during the summer to get your feet wet to the whole thing, and then you hit a Saturday. Starting in I wouldn't try August, because August is the crazy start, but a Saturday in

> September, Saturday in October, [and] a Saturday in November. Pick up again, I wouldn't try December because you've got midterms and Christmas and all that. And then pick up again maybe, January February March. So you could do September, October, November, January, February, and March, so six, so four during the summer six during the year. (Interview, East, 2012, November 28)

Although, Ms. East decided to discontinue the implementation of the Modeling Instruction curriculum, she was able to reflect on her journey and indicated areas of improvement.

***RTOP*.**

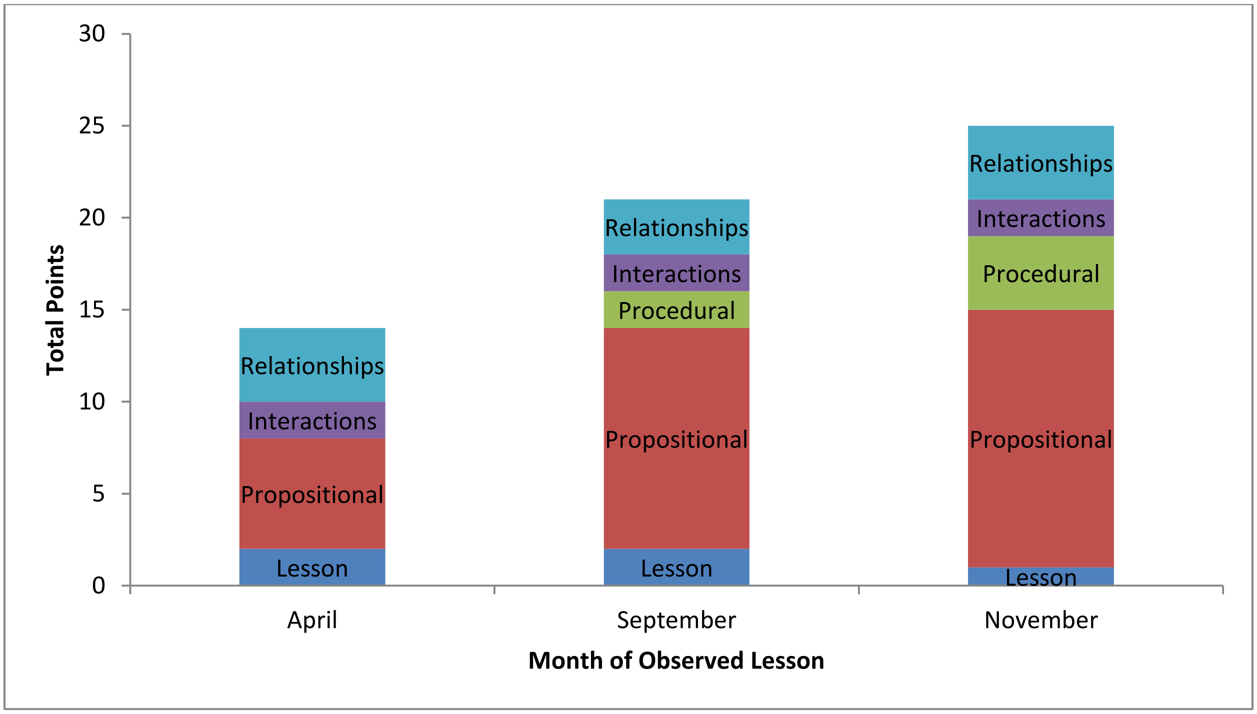

Figure 5. Ms. East scores from each RTOP divided into five categories. From bottom to top: lesson design and implementation, propositional content knowledge, procedural content knowledge, communicative interactions, and student teacher relationship.

The RTOP scores for Ms. East, as shown in Figure 5, continued to increase across all three observational lessons. The increase to Ms. East's RTOP score was completely accounted for in the scores she attained within the content category. An analysis of field notes was conducted to highlight both the subcategories, seen in Figure 5 as, propositional and procedural content knowledge. While there was some fluctuation in RTOP scores of other categories they were not of similar magnitude; therefore, the observed lessons were not analyzed further.

Content.

The largest difference in Ms. East's RTOP score was a gain in the propositional content knowledge category between the initial observed lesson and the post professional development observed lesson. The observers also noted gains in procedural content knowledge after each lesson observed were the same. While the gain noted in propositional content knowledge reported was smaller after the November observation lesson than the first, the increase noted was consistent with the gains in procedural content knowledge.

Propositional knowledge.

The initial score for propositional content knowledge was reported to be the lowest Ms. East received in this category. The observers both noted that the students worked in groups to solve problems related to identifying the number of moles in a hydrate. During the lesson Observer Q noted. "[The] teacher got the groups' attention to clarify [for the class] how to convert units" (Field Notes, Observer Q, 2012, April 18). In the previous example, Ms. East demonstrated her ability to understand the chemistry content, a key aspect of the RTOP section of propositional content knowledge. Observer Q noted further evidence related to the propositional content knowledge as Ms. East's students required her attention for answers. "[Ms. East was] working predominantly with groups in front…A male student has had his hand raised for a while. [The] teacher hasn't noticed, [as] she is helping others. [It appears as if] everyone wants help" (Field Notes, Observer Q, 2012, April 18).

After the professional development the classroom environment in which Ms. East taught had undergone changes that attributed in-part to the increased score in the area of propositional content knowledge. The class being observed post professional development was previously noted by Ms. East as being an inclusion class. The high number of students with diagnosed mental disabilities meant that an educational assistant was assigned to the class, to help aid student learning. The teacher to student ratio was one to twenty during the April observation and one to five for each other lesson observed. The observers noted that Ms. East continued to display a firm understanding of content fundamental to chemistry. Observer Q noted that, "[Ms. East described] significant digits [and] explained [to the students] how to record mass to two digits" (Field Notes, Observer Q, 2012, September 18). In another example Observer J noted that Ms. East associated the multiplication of numbers in mathematics was similar to multiplication of variables in chemistry an area from propositional content knowledge that had not been observed during the initial lesson.

> [The] teacher tells the students not to focus on which side is which [length or height]. [A couple minutes later, Ms. East] went back to the student that was still not understanding [what she meant]. [Ms. East asked the student], "What is the difference between two times three and three times two?"[Student answered, and

> Ms. East asked], "So what is the difference between length times width and width times length?" [Ms. East walked away, the] students worked together to determine how to solve for [the formula] density equals mass divided by volume. (Field Notes, Observer J, 2012, September 18)

Ms. East had time to guide students, not only when they had questions as in the initial interview. "[The] teacher comes by and gets the lost group back on track" (Field Notes, Observer J, 2012, September 18). The cited examples indicated that the increased score for propositional content knowledge resulted from Ms. East presenting a lesson that promoted a strong conceptual understanding that encouraged students to construct a formula from the data they acquired.

Ms. East continued to earn a higher score in the area of propositional content knowledge as in the final observation lesson ionic bonding was presented in a lesson that promoted a strong conceptual understanding of chemistry while being related to mathematics. "[Ms. East was able to] conceptually tie [ionic bonding] to the periodic table and referenced electronegativity" (Field Notes, Observer J, 2012, November, 28). Both observers noted that Ms. East started the lesson by handing each student a baggie that had pink and orange pieces of paper that represented cations and anions. Observer J noted that as Ms. East explained the activity, "[Students were asked to] recall [we] have been writing formulas" (Field Notes, Observer J, 2012, November, 28). The following excerpt from Observer Q noted that Ms. East understood the chemical relationship well enough to guide students.

> [The] teacher begins to explain the activity. [Ms. East asked a question, after the student replied she said,] “John said yes we can, why can we?” The teacher holds up another example. [Ms. East asked] “Why not now [referencing her cation and anion papers]?”[Ms. East] steps the students through how to balance the charges. [She relates the balancing to doubling a recipe. [Ms. East is] asking some good divergent questions – trying to help students see that we just use a reduced form.

In this example Ms. East was noted for using a real world example and encouraging knowledge construction through student engagement both key aspect of the propositional content knowledge section of the RTOP. Ms. East was noted several times for connecting mathematics to the chemistry content. Observer J noted, “[Ms. East used] a comparison to math [specifically] the lowest common denominator. [Ms. East said], ‘Just like in math – multiply’” (Field Notes, Observer J, 2012, November 28). “[Ms. East] relates [content] to math class, the distributive property” (Field Notes, Observer J, 2012, November 28).

Procedural knowledge.

Ms. East received scores, after each observed lesson, that were slightly higher in procedural content knowledge each time. Ms. East received none of the points possible for procedural content knowledge during the initial observation which indicated that students were not noted in the lesson actively engaged in chemistry content. Although Observer Q noted that students’ were on task they were not expected to interact with or present chemistry content. Observer Q noted the actions of one of Ms. East’s students in the following excerpt.

> [Ten minutes into the lesson], most [of the] students seem to be on task, maybe thirty percent mostly off task… [Fifteen minutes into class], a male student on my side hasn't even looked at his worksheet… [Five minutes later], [the] not working male student has had his hand raised for a while... [Five minutes after that], the teacher finally comes to help male student. The male student starts to work. (Field Notes, Observer Q, 2012, April 18)

The previous example indicated that the observed lesson placed little value on student participation another key component of procedural content knowledge.

As previously stated the classroom structure differed for Ms. East post professional development. While the change impacted areas important to the category of propositional content knowledge it is unlikely that it would have similarly impacted Ms. East's score for procedural content knowledge. During the post professional development observation lesson Ms. East used instructional material directly from the Modeling Instruction curriculum. The increased score can be attributed to students' that were noted participating in a lesson, which engaged them with one another and the content. Observer J noted, "[One] student redirects another to keep working… [Ms. East's] students are still working [on finishing their assignment], after the bell rings" (Field Notes, Observer J, 2012, September 18). Observer Q noted several interactions between students that indicated they were comfortable helping one another.

> [One of the] students say, "The instructions weren't clear," and "I hate this class." She seems frustrated, [but] her partner is doing all the measurements. [The

> students worked in pairs.] Another student [stated], “When you actually do your work, time flies. [In another example], one group goes over to help the group that has been perpetually lost. [Five minutes later, the] perpetually lost students are suddenly done. (Field Notes, Observer Q, 2012, September 18)

The gains in procedural content knowledge were a result of student thinking about the content, which were again noted in the final observation lesson.

The area of procedural content knowledge that observers noted growth in related to the students in Ms. East’s class being more engaged in the chemistry content presented during the final lesson observation. The ability for students to present information about ionic bonding in more than one way, mathematically, with paper, and in writing resulted in an increased score for Ms. East in procedural content knowledge. The students in Ms. East’s class were again observed working in groups and were engaged in understanding chemistry content.

> Students [were] working together in small groups. Each [student] has their own set of cards, but [they] are asking each other for help and talking it [student difficulty] out. [The] educational assistant and teacher are floating and helping groups. [The] teacher [is] questioning a student to help him solve [a] problem. [The] students seem to be working and mostly understanding. (Field Notes, Observer Q, 2012, September 18)

The final observational lesson for Ms. East indicated that her growth in the procedural content category of the RTOP resulted in a classroom that encouraged students to be thoughtful about the chemical processes presented during instruction.

Ms. West.

Background.

Ms. West was a Caucasian female in her forties at the time of the study. She had been teaching for eight-teen years. Ms. West was certified to teach science grade seven through twelve. Ms. West shared classroom space with Ms. East, they taught in the same room at different times of the day.

Ms. West taught chemistry in a mid-size city school in the southeastern United States. The school included grades nine through twelve. The statistics for the 2012-2013 school year listed the student population at 2382 students with 76% of the students as white. The school had a 93.6% graduation rate with an average ACT score of 20.7. The student population contained 25.4% that were considered economically disadvantaged and 9.2% of students reported having a disability.

Adaptation.

Initially Ms. West attempted to implement the Modeling curriculum as it had been presented during the workshop. “I've got sticky notes everywhere like, do this different next year, or this is the modified version, or this is what the honors classes used” (Interview, West, 2012, September 19). The sticky notes were a way for Ms. East to reflect on the instructional practices associated with Modeling Instruction as she implemented them in her class. Adaptation to the curriculum was originally something Ms. West intended to implement in the upcoming years. “I think too after going through this once it will be easier to make the adjustments. It's [Implementing Modeling Instruction curriculum is] just stressful” (Interview, West, 2012, September 19). Ms. West thought the experience of using the curriculum as it was given to her in the notebook would help her determine which instructional techniques were necessary. “We [will] kinda know what was effective, and what was, kind of, a waste of a day” (Interview, West, 2012, September 19). Ms. West explained her implementation of the Modeling Instruction curriculum in the following quote.

> I don’t think I do all of the things that we learned at the workshop. I think I have sort of picked out the things that, first I feel comfortable doing and then, I have tried to add in a little bit at a time. (Interview, West, 2012, November 16)

Though Ms. West had intended to use the Modeling Instruction curriculum for the entire school year she describes her adaptation in the following statement. “What we have decided to do is just that we are just going through and kind of the order that we were doing things, but we were using materials from the workshop” (Interview, West, 2012, November 16). The Modeling Instruction curriculum was adapted by Ms. West, the order of units were mixed up, with content being presented in ways that were comfortable for Ms. West.

Facilitation.

Ms. West stated that implementing Modeling Instruction techniques was hindered by the focus on student construction of knowledge developed through interpreting data they collected. Ms. West explained that how she was frustrated with implementation in the following quote. “It's very difficult for me not to just tell them [the students] what I want them to know” (Interview, West, 2012, September 19). When Ms. West attempted to hold students accountable for their learning she experienced resistance from her students. “It's so hard to try to pull it [what she wants them to know] out and it's frustrating for them; because they [the students] want me to tell them what to do” (Interview, West, 2012, September 19). After the workshop on discourse Ms. West stated that her instructional practice had changed in the following way.

> I give them more open ended questions instead of just giving them the answers. If you know what I mean cause we were talking about not saying this is right, this is wrong, and moving on. I try to just say okay, “Well how would you figure this out?” Like for example I would say, “Well what do I do if there’s more than one oxidation number? How do I pick the right one?” Then go back to, “Well we learned about all these oxidation rules which one is going to apply?” and there’s usually someone who can pick it out. (Interview, West, 2012, November 16)

In the previous example Ms. West demonstrated her understanding of how to use of open ended questions to facilitate student engagement.

Pacing.

When asked what topics she would like to see covered in a follow-up Ms. West started with the statement, “mainly pacing” (Interview, West, 2012, September 19). She wanted to know, “Are other people having to leave out things to try to keep the pace?” (Interview, West, 2012, September 19). Previously in the interview Ms. West had said, “My concern is I have no way to know whether I'm on the right pace. [If] I'm on the right track.” (Interview, West, 2012, September 19). The concern that Ms. West experienced was not alleviated when she spoke with others that used Modeling Instruction.

> I had [asked] one of the girls from [a school district that has fully implemented Modeling Instruction] to send me their pacing guide and they've done this several years there. So I kinda felt like I should have some guidance… They were going to cover unit one in twenty-four days. We haven't finished. We're not finished with unit one, and this is the end of our sixth week. So we are behind, I think.” (Interview, West, 2012, September 19)

In the initial interview Ms. West stated, “This is all a different order than what we usually cover” (Interview, West, 2012, September 19). The order in which material was presented was not a part of Modeling Instruction that Ms. West continued to follow. She explained,

> We have not followed exactly the order of the notebook because we kinda felt like we were never going to get out of unit one - it took us a really long time to get that part… So we are not sticking exactly with the order of the book, because

> we're afraid we won't get to the stuff in unit six and seven that we have to cover, if we did that [continued implementing Modeling Instruction in the order recommended]. (Interview, West, 2012, November 16)

The problem that Ms. West identified as being of key importance was summarized in the following statement. "It does take longer to cover the same amount of material, which kinda leads to a big concern...That's a concern trying to figure out a way to speed up the process without losing what we've been doing" (Interview, West, 2012, November 16). Ms. West thought that issues around pacing could be addressed in a collaborative manner. "I would kinda just like for us all to get together as a [school district of] chemistry teachers. And try to put it together so that we are all doing similar pacing. I guess" (Interview, West, 2012, November 16). In this way Ms. West devised a plan that would assist her "to know how are other people [implementing lessons], where are they, and then the end of the year, are we going to cover all of that" (Interview, West, 2012, September 19). While the order was an initial difficulty that Ms. West noted as impacting her implementation ability, ultimately it was the length of time that Ms. West needed to effectively implement lessons that caused her to discontinue use of the curriculum.

Content.

Ms. West stated, "I'm not really going to know till the end of the year did I cover everything I needed to cover" (Interview, West, 2012, September 19). The length of time spent on unit one impacted the amount of content that could be covered. "We are having to do is omit some things…I mean we're just going to have to cut out a lot of the things, which I don't know if that's good" (Interview, West, 2012, September 19). Because Ms. West taught a standard level Chemistry class her students had not previously taken a standardized test, this change to assessment was made during the study. "Now, we found out that we're going to have, that this year chemistry is going to pilot the EOC [end of course exam].So next year we are really going to have to cover all those objectives" (Interview, West, 2012, November 16). In the following quote Ms. West indicated that she would be willing to continue working toward the implementation of the Modeling Instruction curriculum, but covering content was now an important factor.

> Just too kinda see, especially once we know that the EOC test is coming. To see how we can, I don't know if restructure is the right word or not, but see if we can figure out a way to still use Modeling and cover all those objectives. (Interview, West, 2012, November 16).

Initially Ms. West was willing to implement Modeling Instruction; however, she became increasingly concerned about the amount of content that was presented to her students as the year progressed.

Student Understanding.

The development of better understanding of chemistry was a factor that Ms. West noted as a result of implementing the Modeling Instruction curriculum. "I think they do have a better understanding. So I think that's probably the biggest benefit" (Interview, West, 2012, September 19). Ms. West noted the structure of implementation that assisted students in the development of chemistry knowledge from Modeling.

> I think they get it once you actually have gone through the whole deal. Like you do the lab, and you do the white boarding, and you have the board meeting, and all that sort of thing. I think they do have a better understanding. (Interview, West, 2012, September 19)

Ms. West explained how students interacted during lessons in Modeling Instruction in the following quotes. “They’re talking to each other more than they are listening to me and it. They [the students], seem to be more involved in what’s going on [during class]” (Interview, West, 2012, November 16). She also noted that students helped each other to develop understanding. “I’ve been saying this for two weeks, and their friend says, ‘Oh but look, here’s where she’s getting that.’ And somebody standing right beside them is able to teach them. So I think that has been a big plus” (Interview, West, 2012, November 16). The change in class structure was not an area that Ms. West indicated as being problematic to implementation. “I like the more student-oriented thing instead of me standing there doing it, and them copying it down. I like them being more accountable for what they're learning” (Interview, West, 2012, September 19).

Student Participation.

Ms. West noted very few problems with student participation. During her implementation she said, “They [her students] like working as a group instead of all by themselves” (Interview, West, 2012, November 16). In regards to instructional techniques related to Modeling lessons Ms. West stated, "This gives them a chance to actually still get up and move around and do stuff and work as a team" (Interview, West, 2012, November 16). Ms. West did note that in one of her classes working in teams was difficult. "This class has around ten kids and several of them are on the lower level of, I don't know if you would say skill. I mean they are pretty intelligent they just don't like to participate" (Interview, West, 2012, November 16).In general Ms. West stated that the students were positively impacted by her use of Modeling techniques. "They like the lab activity, because - I have actually had kids say, 'Are we ever going to get to do more labs?'" (Interview, West, 2012, November 16). In the previous quote Ms. West highlighted her students' desire to engage in learning chemistry as a result of the Modeling professional development.

Student Ability.

Ms. West noted two aspects of students' ability that impacted her implementation of the Modeling Instruction curriculum. Ms. West has previously noted her appreciation for the student-centered nature of the Modeling Instruction curriculum. In the following quote she explained how her students reacted to being held more accountable for their learning,

> Very frustrating because they're not used to that…They [the students] want you to lay it out. "Give me what problems you want me to do out of the book, and I'll do it. Tell me what it is and I'll do it. Just don't make me have to think." And that's

> hard, I mean that's hard - and especially with lower level kids. (Interview, West, 2012, September 19)

When Ms. West was asked to clarify her meaning of level of student, she said.

> I'm teaching the lowest chemistry offered…I have many students who failed Geometry flat out. I have a lot of kids who failed Algebra one, and had to take in summer. I have very low level math kids, which is the challenge because; I'm having to teach the basic math and the chemistry. That's what's slowing me down I think. (Interview, West, 2012, September 19)

Ms. West stated previously that the instructional techniques of Modeling Instruction required her to spend more time on one unit. Ms. West stated, “I don't know that I could have gone any faster with the level of student that I have” (Interview, West, 2012, September 19). Ms. West noted that student math ability and student ability to be accountable for learning were both factors that contributed to the decreased pace of content presentation.

Social.

The administration was not a factor that Ms. West noted as being a hindrance to implementation of Modeling Instruction.

> I don’t know how to say this really. They don’t really know what goes on in my classroom, unless they are coming to observe me, which they did that the other day. I was doing a whiteboard - It was during the review thing [explained in the instructional section]. I’ve heard that they like what we’re doing, when they see

> what we're doing. They like that they're [the students are] in groups. They like that they're up doing stuff. They love the white boards because it's instant feedback, and that's one of the things that they're trying to really work on right now - is that the kids get some sort of assessment every day as to what you're doing is it good? Is it bad? Is it right? Is it wrong? I don't know if they know that what we're doing is Modeling. I think that they just see it as more interactive teaching and so that's. They do like that, but I don't know that they realize it is Modeling (laughter) I mean - you know. (Interview, West, 2012, November 16)

Although the administration was not something Ms. West noted as a difficulty with implementation. Social interactions in other areas of Ms. West's instruction were a factor she mentioned.

Ms. West noted several factors that related to her peer structure as making Modeling instruction difficult to implement. Ms. West explained how the implementation from another district differed from hers in the following quote.

> They start that as a freshman, they start Modeling with that princ - what's that physics - yeah, they do that. And then they do every level of their science once they get to high school they have to choose a track. And we don't have an option ours is just typical there's like four people in our whole high school doing this Modeling thing and it's just so different (Interview, West, 2012, September 19).

Ms. West noted, in the previous quote, that she had difficulty with implementation that might not occur elsewhere because only a few people knew about the Modeling Instruction techniques.

> Our issue is finally everyone agreed to do it, okay, to do the Modeling. The problem is that not everyone was in the Chemistry Modeling workshop. [Ms. Central] who's teaching the standard [chemistry] level she went to the Physics Modeling. So she at least knows because she's teaching the [Modeling] physics. So she at least knows what Modeling is and she's doing what we're doing on a day-to-day. [Ms. Down] teaches the honors levels. She's struggling with the Modeling because she feels like, it's not - she's not going fast enough. She's not going to get in what she wants to get in. She's about to decide to pull out of Modeling. The advanced teacher, [Mr. Up] who didn't go to the workshop at all is [Ms. Down's] husband. He isn't very; he agreed day one to do it. After about two weeks, he's not. He's gone along doing his own thing. (Interview, West, 2012, September 19)

Ms. West noted that the teachers in her professional learning community had differing views in regards to Ms. Down, Ms. West stated.

> She [Ms. Down] was like, 'Oh I've heard a lot of great research about that [Modeling Instruction]. I know that's a new thing coming out, and oh I think that's great. I'm really excited that y'all are willing to try the new things.' She's curious

> to see how it's going to go. So she is very supportive, but she's really into trying new things which is good. (Interview, West, 2012, September 19)

When questioned about the possibility of trying again to implement Modeling Instruction as a department Ms. West stated,

> No, no data in the world. No. And partly it's because his [Mr. Up's] belief is, which is true. That's not what they're going be doing when they get to college. And all of his kids are college bound like high level college bound kids. And he wants them to know everything they need to know in the way, the way they are going to have to do it when they get to college, which is basically lecture…That's his, that's where he's coming from. (Interview, West, 2012, September 19)

Although the chemistry department at her high school was not implementing the Modeling Instruction curriculum Ms. West recommended district level collaboration.

> It would be helpful to work with, maybe other teachers in our [district] who might be doing Modeling…I think if we could all get together and use this [the Modeling Instruction curriculum] because there's several of us who are trying to do the Modeling thing- and, if we could all just get together and figure out how to make it work to cover all the stuff. (Interview, West, 2012, November 16)

Ms. West noted that students would benefit from working together. "It's really hard on the kids when they move especially within the [district]. And we're getting a lot of kids, way more than usual moving into our system" (Interview, West, 2012, November 16).

Ms. West noted that she would have appreciated interacting with other teachers experienced with Modeling Instruction for several reasons.

> I would like to see what other people are doing besides what's just in my notebook. I've gone online and look at other people's syllabus, and even their daily stuff. And you can click on things that they're doing that week. And I'm seeing a lot of things that are not in that notebook… I would like to see the differences in say what a standard teacher is doing versus a higher level, like an honors person. (Interview, West, 2012, September 19)

Ms. West noted that having peers or at least a social network of others using instructional practices found within the Modeling Instruction curriculum would have been helpful during Implementation.

Instructional.

Ms. West attempted to implement Modeling Instruction in her classroom. “I really tried to completely change it [instructional practices], I've which - has been kind of hard” (Interview, West, 2012, September 19). In the following statement Ms. West explained how the post professional development observed lesson was not typical in her instructional practices.

> I think today was pretty normal for lab, for lab days. The only difference being that usually, I explain what exactly they're going to do. This was kind of more of a discovery thing, where they [the students] sort of have to figure it out, but it's because we have done a lab on mass. We have done a lab on volume. This was

> just putting it all together. So, typically, I guess there's more direct instruction of what to do. That would be kind of the difference I guess. (Interview, West, 2012, September 19)

The changes that Ms. West attempted to implement were noted as being difficult to maintain during the initial interview she stated.

> I have a whole filing cabinet full of what I've always done, and I've not opened it once… It's been very hard. Well to not go back to what you're comfortable with, has been very hard...Part of the stress is it's hard if it's not what you've been doing. I mean it's hard not to pull open that filing cabinet when I know I've got four-teen years of stuff in that filing cabinet. And four-teen years worked out pretty good. (Interview, West, 2012, September 19)

As noted previously Ms. West did not continue with implementation of the Modeling Instruction curriculum. Although she stated, “With the Modeling you can sort of break up what you’re doing into sort of little groups little mini-lessons” (Interview, West, 2012, November 16). The instructional materials that Ms. West stated she continued to use were whiteboards and worksheets. When she was asked why she used a Modeling Instruction worksheet Ms. West replied.

> We’re trying to use that stuff because number one it’s good stuff; but it’s also different than the stuff we already have. And gosh I have probably twenty pages of practice stuff for this, but it is kinda nice to have something new to look at… I like the way it was organized, like it had this info. This is how you do this

> particular kind of problem, and then you flip over, and you have five or six practice ones. And then here is what this does with roman numerals, and then you flip over and here's some roman numerals. So it's kinda nice to have it broken up into sections like that when their first learning the skill. (Interview, West, 2012, November 16)

In another example of how Ms. West used Modeling Instructional materials in her classroom she mentioned her use of whiteboards for review.

> [Working in groups] has helped when we do reviews and stuff like that. Like when we reviewed the day before yesterday for the big test we took yesterday. And the review was all using the whiteboards…They were in groups, and we went over like some vocabulary terms at first, and we went over actually drawing things and practicing doing things. And they were actually teaching each other. (Interview, West, 2012, November 16)

Although whiteboards were not used during the observed lesson, which was a shortened class period because of a pep rally, Ms. East explained how the final observational lesson would have differed in the following statement; she highlights her use of whiteboards.

> I probably would have gone over those examples and then I would have given each group a white board and then kinda so I could check what they were doing a little bit more quickly you know more direct feedback, but because of the time I knew if we did that we wouldn't get very far" (Interview, West, 2012, November 16).

Ms. West indicated that she started the school year by completely changing her instructional practice to implement the Modeling Instruction curriculum. Ms. West stated during her final interview that she continued to implement some of the instructional techniques for the professional development.

RTOP.

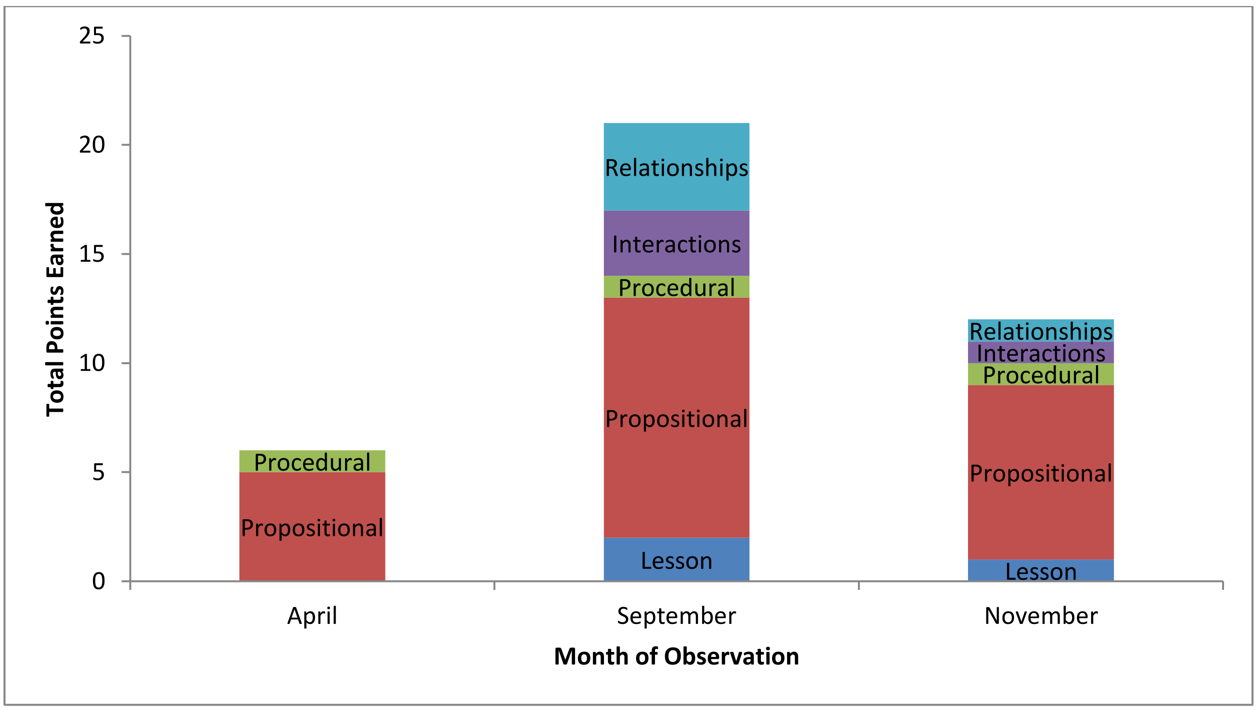

Figure 6. Ms. West scores from each RTOP divided into five categories. From bottom to top: lesson design and implementation, propositional content knowledge, procedural content knowledge, communicative interactions, and student teacher relationship.

The RTOP scores for Ms. West, as shown in Figure 6, indicated that her classroom was more student-centered after the summer professional development. From the initial observation to the final observation Ms. West's growth was reported in all but one category from the RTOP. Ms. West's score improved the most in all categories during the observational lesson post summer professional development. The areas that initially increased also declined between the September and November lesson observations. The greatest changes were noted by observers in the category of classroom culture. The field notes were analyzed to determine what practices were cited that pertained to both the relationship between teacher and students', as well as the communicative interactions. Although the next highest growth was noted in propositional content knowledge, the notes were examined for changes in Ms. West's lesson design and implementation. The lesson design and implementation section was also not noted in the original observation, but contributed to Ms. West's score only after the professional development.

Classroom culture.

As seen in Figure 4, Ms. West was not observed creating a classroom environment that encouraged student engagement during the initial lesson observation. Both the contributing areas of communicative interactions and student/teacher relationship gained after the professional development. The trend in classroom culture continued to change as a decrease was noted between the post observation lesson and the final observation lesson.

In the initial observation lesson Ms. West received no points in the categories on the RTOP related to classroom culture indicating that student engagement was not reported. During this lesson Ms. West was noted by both observers as having explained to students how the problems they were to complete were supposed to be worked. The following comments, by Observer Q demonstrate how Ms. West was observed interacting with her students. “[The] teacher works a molarity problem on the overhead… [The] teacher passes out a worksheet. [The classroom of] students work, quietly and independently, [on completing their worksheets]” (Field Notes, Observer Q, 2012, April 18). Similarly Observer J noted, “[Ms. West’s] students [were] working quietly and individually at their desks” (Field Notes, Observer J, 2012, April 18). The interactions between teacher and students that were noted during the initial observation lesson indicated that students would approach Ms. West when they needed assistance, but the only other interaction noted was not positive. Observer Q reported, “[The] teacher called out a student for possibly trying to write down answers on worksheet [of another student, which he was grading] - [the] student [looked] annoyed” (Field Notes, Observer Q, 2012, April 18). The field notes indicated that Ms. West was not implementing instructional techniques indicative of a student-centered classroom culture either through encouraging students to communicate with one another, or by encouraging students to engage in discussion with her about chemistry.

Communicative interactions.

The scores received by Ms. West in the category of communicative interactions resulted from the noted classroom practices that pertained to the quality and quantity of student communication. During the post professional development observational lesson Ms. West attempted to engage students in classroom conversation by asking questions. "[Ms. West asked], 'How do you measure volume?' [She] asked two students – no answer [was given by them]. Another student [answered Ms. West], 'graduated cylinder'" (Field Notes, Observer J, 2012, September 19). Ms. West had changed the structure of the classroom and expected students to work together in the following excerpt Observer Q noted the behaviors displayed. "[The] students divide themselves into groups and got to lab tables. [Ms. West asked a student], "Are you just thinking a lot?" (Field Notes, Observer Q, 2012, September 19). Ms. West was noted encouraging students to interact during the post observation lesson, a key aspect of the communicative interaction section of the RTOP. Observer Q noted, "Most groups seem to be on task now… [Ms. West] reminds them [the students] to all be participating. The score earned by Ms. West during the final observational lesson most notably Ms. West was not observed using questioning to facilitate student engagement as she had during the previous lesson. Observer Q noted, "She [Ms. West] is giving all the answers – she asks questions, but answers herself" (Field Notes, Observer Q, 2012, November 16). Observer J noted, "[The] teacher is doing most of the talking." The students in Ms. West's class were observed assisting each other.

> She [Ms. West] floats around the room answering questions. [The] teacher tells the student to write IV. He's completely lost. When the teacher leaves another student at the table explains. [The student said] "The math is tricky." (Field Notes, Observer Q, 2012, November 16).

Although Ms. West's score had declined slightly from the post professional development observational lesson, the field notes indicate that Ms. West was still encouraging students to work together rather than sit quietly and complete assignments.

Student and teacher relationships.

Ms. West improved her RTOP score in the category of classroom culture that was related to student/teacher relationships. Ms. West was noted acting as a resource for her students in that she is not explicit in her directions, one of the areas important to the RTOP relationship category. Observer J noted, "[Ms. West said,] 'I am not telling you what to do step by step - you will need to work as a team to figure it out'" (Field Notes, Observer Q, 2012, September 19). Ms. West was noted encouraging student engagement. "[The] teacher walks around, announcing reminders, and getting groups on task" (Field Notes, Observer Q, 2012, September 19). The observers noted that Ms. West continued to encourage students, and demonstrated patience by allowing students all class to work on solving the problem. At the end of the lesson Observer Q noted, "One group wants help. [Student] asks the teacher questions and she agrees to answer. She [Ms. West] steps them [the students] through how to solve it [the problem]" (Field Notes, Observer Q, 2012, September 19). The patience displayed by Ms. West accounted for part of her increased score in the student/teacher relationship category of the RTOP. Similar patience and questioning techniques were not noted by observers in the final observational lesson. Both observers reported that Ms. West was not allowing time for students to answer questions before answering them herself.

> [The teacher did] not really [allow questioning to guide the development of student ideas]. She questioned the students some, but the questions were low level and the teacher didn't even wait for students to answer. She answered [the questions] on her own. (Field Notes, Observer Q, 2012, November 16)

Ms. West's score for the student/ teacher relationship category of the RTOP was not zero because she continued to work with students as they asked questions and worked in partnerships.

Lesson design and implementation.

Ms. West was also not noted as having behaviors that were important to receiving a score in the lesson design and implementation category during her initial observation lesson. The lesson that Ms. West presented during her post professional development observation lesson was part of the Modeling Instruction curriculum. Ms. West was noted by Observer Q expressing to her students that she expected them to develop a solution to determining the thickness of aluminum foil.

> [The] teacher explains the assignment… [She says], "This activity is different because I am not going to tell you exactly what to do. You have to work as a team to figure it out.'[Ten minutes later, Ms. West said], "I'm not answering questions

> you're going to have to figure it out."[Ten Minutes later the] teacher reminds students about the important fact on the front of the sheet that will help them solve the calculation. (Field Notes, Observer Q, 2012, September 19)

Although Ms. West received her highest score in the lesson design and implementation category of the RTOP during the post professional development lesson because the lesson was designed to encourage students participation Observer J noted.

> Yes, [the students were working with data to build ideas]. The students were doing a lab in which they were given properties of Aluminum and they were supposed to find the thickness. Ms. West still ended up giving them formulas, so they could work out the problems. (Field Notes, Observer J, 2012, September 19)

During the final observational lesson Ms. West's score in student-centered lesson design and implementation declined from where it had been during the previous lesson. Ms. West is once again noted working through example questions, but now encourages students to work in teams. As noted by Observer Q,

> [The] teacher [is] talking. Students take a long time to quiet down, and some continue to chatting while she talks. [The] teacher passes out notes that have been printed off. [The] teacher begins talking about how to name compounds. [The] teacher works through some examples on [the board from] the worksheet. (Field Notes, Observer Q, 2012, November 16)

The change in lesson design and implementation may have been negatively impacted by the shortened class time Ms. West had stated that she intended to have the student use whiteboards.

CHAPTER FIVE: DISCUSSION

The discussion will focus on the core concepts of content, active learning, coherence, duration, and collective participation. The concepts as outlined by Desimone (2009) will each be addressed; the lens used will be my evaluation as interpreted through my experience as the participant observer. The teachers' similarities and differences will be examined more closely. Finally the relevance of the teacher metaphors Inexperienced Survivor, Experienced Talker and Chalker, Pragmatic Adjuster, and Revolutionary Charger will be addressed (Stronkhorst & Akker, 2006).

The concept of content focus was established by the Modeling Instruction curriculum during the summer professional development in which the teachers participated as students of chemistry. The content provided during the professional development focused on promoting important conceptual representations of chemical processes. The collaborative nature of Modeling Instruction allowed content-based misconceptions to be addressed by other teachers rather than by the facilitators in most cases. The data collected from the teacher observations supported the relevance of the chemistry content knowledge provided during the professional development, resulting in increased scores in the teachers' propositional content knowledge.

Active learning within the Modeling Instruction professional development included working through the curriculum as students. Working through the materials provided as students allowed teachers and observer to experience Modeling Instruction as experts, the facilitators, were delivering the pedagogy. The process allowed teachers to explore the content within the Modeling Instruction curriculum while engaged in instructional techniques that were unfamiliar, such as board meetings. By asking the teachers to act as students, we were able to identify areas where students may have difficulty. Although the teachers were able to see unique aspects of the lessons being a student, the teachers were not active in practices, such as facilitating class discussion, that were needed to develop the skills necessary to implement instructional practices related to Modeling Instruction.

The professional development was designed to last 88 hours, although the participants in this study had only 81 hours, this still well exceeded the recommended minimum of twenty. Interestingly, although none of the teachers were able to participate in the full-day event even though they had all agreed to do so, some teachers noted that more time to understand the Modeling Instruction practices would have been helpful. The summer professional development was an intense two-week course and at least one teacher explicitly stated that assistance during the school year would have been helpful to implementation. The teachers indicated that more interactions with mentors familiar with the pedagogy fundamental to Modeling Instruction over a longer timeframe, similar to the professional development described by Donnely and Argyle (2011), or simply additional opportunities for engagement with others implementing instructional strategies related to Modeling Instruction, would have increased their ability to implement effectively. Time Span seems to be an important factor when considering number of contact hours.

During the professional development, students, teachers in the study were collective participants in that everyone taught high school chemistry or had an interest in teaching chemistry. In the case of this study the teachers were from the same district and occasionally the same school. The schools that had more than one teacher in the Modeling Instructional professional development did not have unanimous participation in adopting the curriculum within their chemistry departments. The data indicated that peer beliefs may have impacted teacher implementation.

Coherence was the one critical factor put forth by Desimone (2009) that was not followed in the Modeling Instruction professional development, although it was a goal of the TIME grant to align the curriculum with current state standards. Teachers were concerned about the ability to address all the content standards required by their district. As noted when discussing collaborative participation, individual teacher beliefs as well as peer beliefs impacted the instructional practices, of the participants. The data indicated that coherence between teachers and the people they collaborated with would have improved implementation fidelity.

Each teacher who came to the professional development did not arrive as a blank slate – just like their students do not come to them without having previously formed some ideas about chemistry concepts. Similar to students in a classroom, these teachers developed their own constructs of Modeling Instruction. Many variables impacted the knowledge construction, but analysis provided some insight into the teachers' construction by examining stories of each participant as the study occurred.

During the interviews and observations, the teachers talked about chemical demonstrations that they had observed together during the professional development. When describing their classes' implementation, the indication was that this study allowed the teachers to form a connection point with me as the participant observer, forming a relationship based on our shared experience in construction of our understanding of Modeling Instruction. This relationship allowed the teachers to express concerns and difficulties about the pedagogy without having to explain the content. The teachers appreciated the information presented at the follow-up workshop. The teachers indicated that collaboration with others a guide/mentor could help them through the evolution of their educational paradigm.

While the teachers had many different thoughts on Modeling Instructions curriculum/techniques, a few were more common. First, the teachers appreciated the particulate representation of matter being used in Modeling Instruction as a way to develop student understanding. The other notable agreement was related to student cognitive ability – when students were low either in critical thinking skills, participation, or mathematical skills, the amount of time needed to complete Modeling Instruction lessons increased. Ms. East said students on both sides of the ability spectrum struggled with participation in Modeling Instruction, while Mr. South felt his higher-achieving students engaged well with Modeling techniques. Being sure that students were prepared for college chemistry was noted by all but one of the teachers as a top priority. 'Prepared' did mean different things to Ms. East (students being prepared for lecture instruction) and

Ms. North (students prepared by covering concepts). Interestingly, neither had talked to college chemistry professors about their expectations of high school students entering their classes, but instead relied on word-of- mouth from students or peers.

Ms. North went from being a good teacher to an excellent facilitator and back again in regards to the student-centered nature of her classroom. She was the only teacher who appeared to fully understand the pedagogy behind the Modeling Instruction approach, and appeared to be an expert at implementing student-centered instruction. Ms. North demonstrated this understanding when she synthesized her curriculum with the Modeling Instruction curriculum. As an observer in Ms. North's room during her board meeting session, I noticed that she made the facilitation of student ideas appear easy. Her decision to stop implementation of Modeling Instruction was difficult, because she understood that her students would be trading breadth of knowledge for depth of understanding. Atomic theory, not being a part of Modeling Instruction curriculum, was a stumbling block for Ms. North because of the understanding that it lends to the conceptual understanding of chemistry. The way in which Ms. North demonstrated her use of whiteboards indicated that she used them to evaluate student understanding and encouraged the questioning of student misconceptions.

Ms. East had a very different experience, as her classroom RTOP scores gained steadily with each observational lesson. The classroom environment that Ms. East established prior to attending the professional development had been teacher centered although the students worked in groups. She demonstrated practices that indicated she was a novice at student-centered instruction, although she initially indicated that she was not a novice. Ms. East realized that teaching physics using a student-centered approach seemed easier as she experienced difficulty implementing Modeling Instruction techniques. Ms. East noted that the change was challenging. While she noted many problems - the ones that stand out most to me were her beliefs about student ability and her view of student-centered instruction versus lecture. As participants of the workshop teachers identified misconceptions in one another about chemistry, this helped the teachers to develop a better understanding of the benefits in student learning. In addition, the binder received from the professional development included many research articles published in the past half-century that indicate that students' abilities to cognitively flourish improved when instruction is student-centered. The data indicated that personal experience and social factors were important contributors to the mental model Ms. East formed and maintained in regarding chemistry education. Ms. East continued to implement more student-centered strategies in her classes as the study progressed.

Ms. West indicated that she had always used the textbook with a classroom environment that included students quietly working in a teacher-centered lesson. The change from teacher-to student-centered instruction that was required to implement Modeling Instruction caused her discomfort and stress. Ms. West felt very comfortable telling her students what she wanted them to know. As Ms. West continued with implementation, she could give examples of students teaching one another with some excitement. The instructional techniques required to teach Modeling Instruction were difficult to implement, were underappreciated by her peers, and took longer to teach the same amount of content. The increased effort by Ms. West was indicated by her improved RTOP score, and the decision to cease implementation of Modeling Instruction resulted in the lower RTOP score. Ms. West explained that she was becoming a more student-centered teacher slowly, expanding her comfort zone, but not as stressful for her as it had been initially. The need to change had become important to Ms. West, based her understanding that Modeling Instruction would benefit her in students understanding and the acknowledgement that the Modeling Instruction curriculum provided good content material.

Mr. South's initial instructional techniques fell somewhere in between a traditional teacher and a student-centered teacher. Mr. South did not believe that he had the autonomy to implement instructional changes while the other participants of the study did. The comments from Mr. South indicated that he felt that the scope and sequence of the district had to be followed. He indicated that his priority was to be sure to ensure the standards were covered in class, and if the class had not completed their discussion, Mr. South would tell the students what they needed to know. Mr. South did not view Modeling Instruction as something that would work for all his students, but thought that a completely different class with differentiated instruction should be taught. The idea of having segregated instruction was a little troubling to me, as segregation indicated that different populations of students learn differently therefore need unique instruction. One of the core features of Modeling Instruction is collaboration, because collaborative learning research has shown that students' conceptual understanding flourishes not as an individual, but rather as members of a team. Mr. South was a member of a team that had decided not to implement Modeling Instruction, and he did not disagree with that choice. Mr. South stated having difficulty keeping up with the number of preps he had already, adding another class to prepare for Modeling Instruction seemed inefficient.

The teachers in this study all demonstrated that they had gained an understanding of Modeling Instruction from being a student-centered curriculum. Each of the teachers also stated the desire to implement Modeling Instruction to various degrees. Both Ms. North and Ms. West received high marks and praise by their administration when they used techniques from Modeling Instruction indicating that the strategies from Modeling Instruction were desirable. The teachers also demonstrated that they had gained an understanding of important instructional materials/techniques of Modeling Instruction which included both the use of white boards and using questions to engage students. The professional development did appear to impact the teachers' constructs of teaching chemistry, as all the teachers had improved scores within the propositional content knowledge category of the RTOP after professional development. The higher scores and interview data combine to show that each teacher attempted to implement at least some aspect of Modeling Instruction and each gained insight that increased their ability to promote a more coherent understanding of chemistry.

The labels that emerged from the work of Stronkhorst and Akker (2006) of Inexperienced Survivor and Pragmatic Adjuster were useful in categorizing three of my four participants. Mr. South had been teaching for three years and had three preps. In his mind, changing his teaching practices in ways that differed from the district was not plausible – Inexperienced Survivor. Both Ms. West and Ms. East made very slight changes to their practices which resulted in increased RTOP scores, and both noted being more cognizant of using student-centered instructional techniques – Pragmatic Adjuster. Ms. North being an already reform-oriented teacher did not fit the metaphor of Revolutionary Charger, but was more of a Revolutionary Adjuster. Ms. North was not willing to risk her student happiness or educational gains, but was willing to attempt implementation of a new student-centered approach.

CHAPTER SIX: CONCLUSIONS

The Modeling Instruction professional development had an important impact on the teachers that participated. The level of impact along with the implications for future professional development was evaluated as they pertained to the original research questions. The limitations of this study were examined and areas of future research were introduced.

How well did chemistry teachers implement Modeling Instruction in their chemistry classrooms, after attending a two week summer workshop? Not surprisingly, the extent to which teachers implemented Modeling Instruction varied. Each teacher stated that they had adapted their teaching practices after the professional development to be more student-centered in practice. The teaching metaphors of Inexperienced Survivor and Pragmatic Adjuster (Stronkhorst & Akker, 2006) provide insight into the behaviors exhibited in three of the participant case studies. The new teacher metaphor of Revolutionary Adjustor was used to categorize the final participant's behaviors. The term Revolutionary Adjustor was created to include teachers that exhibit student-centered practices throughout their professional development experience.

What factors do teachers think will impact their ability to implement Modeling Instruction? The answer to this question also varied, although every teacher mentioned coherence to state standards. Coherence was the major factor impacting the teachers' ability to implement. Because of the uncertainty associated with their ability to complete the course content requirements from the district. The announcement of an end-of-course exam preceded the teachers' decision to discontinue the use of the Modeling Instruction curriculum, even after the teachers had received positive evaluations when implementing Modeling lessons. Student ability was noted as being another factor that influenced teacher use of Modeling Instruction, as instructional differentiation, between students of various abilities was required. Additionally, teachers noted the amount of time required to teach students using the Modeling Instruction techniques was more than could be afforded and more than what was needed for their original instructional pedagogies.

Does a follow-up workshop focusing on discourse have an impact on teacher implementation? The observations indicated that a follow-up workshop had very little influence on the implementation of student-centered instructional practices. In contrast, during interviews the participants indicated that the follow-up workshop was beneficial to implementation. The results showed that the follow-up workshop impacted the teachers' mindsets in relation to student-centered instruction.

What further support could be given to alleviate impediments to implementation? The teachers each indicated that a pacing guide that aligned the Modeling Instruction curriculum to the state standards would have improved their ability to implement. Participants stated that having the Modeling Instruction professional development with collaborative participation continue throughout the school year would have supported implementation.

Limitations

Limitations to this research include those that result from conducting qualitative research and participants that were not representative of the impact of the complete Modeling Instruction professional development. This study was qualitative in nature and therefore is not generalizable to a larger population. However, the case studies presented here can be used as exemplars to create a model for teacher adaptations related to student-centered instructional practices.

The Modeling Instruction professional development, designed at Arizona State University, has a duration of three weeks; this study implemented a two-week workshop. The participants of this study also did not complete the full day follow-up workshop; as a result, they were not exposed to the alignment of the state curriculum. As such, the participants did not experience the full impact of the Modeling Instruction professional development provided by the TIME grant.

Implications

As a country, we put a lot of emphasis on the ability of professional development programs to impact our teacher practices. The case studies performed in this research study indicated that there may be variables within the factors of coherence and collaborative participation that prevented successful implementation of Modeling Instruction. Importantly, all the teachers indicated that while implementing Modeling Instruction lessons, they believed that students attained a deeper understanding of chemistry concepts.

Apart from the alignment of curriculum, other areas of concern for teachers within the factor of coherence included student ability and the pacing of student-centered instruction. Teacher belief as pertains to student ability appeared to be a variable that should be evaluated further. In tandem with the belief about student ability was the belief that college-bound students should be prepared to learn from lecture instruction, which indicated that teachers may hold misconceptions about learning that could be addressed. Chemistry teachers in general have received far more education about student learning than most professors of chemistry, representing one area that could be explored as a misconception. In addition, the time that teachers needed to get through one unit of the Modeling Instruction curriculum was a detriment to its implementation. Teachers would benefit from additional practice implementing student-centered lessons with an expert evaluation of the lesson.

Duration itself did not seem to be a factor that impeded implementation, although the collaborative participation that occurred during the professional development may have assisted more in implementation. Teachers indicated that the change to Modeling Instruction was difficult, particularly when the entire department was not attempting to adopt the curriculum. The ability to continue conversation around the benefits of using the Modeling Instruction alleviated some of the stress associated with being the only teacher implementing this program at their school. This study lends support to the key factors that Desimone (2009) identified as being important in the design of professional development, and the categories that were developed by Stronkhorst and Akker (2006).

Future Research

Research into the impact of professional development on teacher practice is just starting to gain an empirical base. The results of my research indicate that there is a need for a measure to explicitly evaluate teacher fidelity of implementation. The fidelity of implementation research should be refined to identify the importance of teacher adaptations or synthesis of their practice to the material presented in the professional development. Although it may matter if the teacher implements the curriculum exactly, my results indicate that implementation was most successful when synthesized into the teacher's current student-centered curriculum.

The factor of coherence was of great importance to the teachers in my study. Future research should include evaluations of teacher practices when they have alignment with the district standards. It would be beneficial to have a deeper understanding of how teachers define "meeting the standards" for their students. Furthermore can the teacher metaphors used to categorize teachers as they develop student-centered practices be generalized? If teachers can be generalized into these categories, it might be beneficial to create cohorts with teachers in various stages of student-centered practice. We have begun to define characteristics of teachers that are student-centered in practice. Teacher beliefs as well as mindset about students and instructional practices should be evaluated in regards to their ability to successfully implement student-centered curriculum.

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APPENDICES

APPENDIX A: IRB EXEMPTION

MIDDLE TENNESSEE
STATE UNIVERSITY

March 8, 2012

Amy Phelps, Angela Barlow, Tasha Frick, Heather Barker
Department of Chemistry
Angela.barlow@mtsu.edu , amy.phelps@mtsu.edu

Protocol Title: "Transforming Instruction through Modeling Experiences"
Protocol Number: 12-254

Dear Investigator(s),

I found your study to be exempt from Institutional Review Board (IRB) continued review. The exemption is pursuant to 45 CFR 46.101(b) (2). This is because your study consists of educational procedures, and information is obtained in such a manner that human subjects cannot be identified.

You will need to submit an end-of-project report to the Office of Compliance upon completion of your research. Complete research means that you have finished collecting data and you are ready to submit your thesis and/or publish your findings. Should you not finish your research within the three (3) year period, you must submit a Progress Report and request a continuation prior to the expiration date. Please allow time for review and requested revisions. Your study expires on **March 8, 2015.**

Any change to the protocol must be submitted to the IRB before implementing this change. According to MTSU Policy, a researcher is defined as anyone who works with data or has contact with participants. Anyone meeting this definition needs to be listed on the protocol and needs to provide a certificate of training to the Office of Compliance. Once your research is completed, please send us a copy of the final report questionnaire to the Office of Compliance. This form can be located at www.mtsu.edu/irb on the forms page.

Also, all research materials must be retained by the PI or **faculty advisor (if the PI is a student)** for at least three (3) years after study completion. Should you have any questions or need additional information, please do not hesitate to contact me.

Sincerely,

Emily Born

Emily Born
Compliance Officer
615-494-8918

APPENDIX B: SCHOOL PERMISSION LETTER

DATE

Project TIME
MTSU Box 145
Middle Tennessee State University
Murfreesboro, TN 37132

Dear Mr. Brown:

I am writing today to indicate that TEACHER'S NAME has my permission to participate in the activities associated with Project TIME. I understand that these activities include both classroom observations and student assessments.

With regard to classroom observations, personnel associated with Project TIME have permission to observe TEACHER'S NAME classroom and audio-record the instruction. With regard to student assessments, TEACHER'S NAME will be responsible for administering the content assessment to his/her students. I understand that this data is being used as a means for evaluating the effectiveness of Project TIME and no information will be gathered that could be used to identify the students in TEACHER'S NAME's class.

Thank you for allowing TEACHER'S NAME to participate in Project TIME.

Sincerely,

PRINCIPAL'S NAME
Principal

APPENDIX C: INTERVIEW PROTOCOL

Interview questions for teachers prior to workshop intervention:

1. Would you describe today as an atypical instructional day?

2. How has the developmental class on problem based modeling impacted your instructional practices?

3. How are the modeling techniques working in your classroom? (discuss any difficulties with probing questions)

4. In regards to modeling techniques, what strengths did you find once implemented in the classroom? And what weaknesses?

5. Have you had any feedback from your administration?

6. Have you shared any of the modeling techniques with your coworkers?
   Their thoughts?

7. In a follow up workshop what topics would support you to successfully implement modeling in your classroom?

Interview questions for teachers after the workshop intervention:

1. Would you describe today as an atypical instructional day?

2. What impacts have you noticed to your instructional strategy since the follow up workshop?

3. I noticed that you changed *instructional practice*, what made you decide to implement that technique?

4. How have the modeling techniques changed in your classroom?

5. What differences have you noted in the classroom?

6. Have you had any further feedback from your administration or thoughts from your coworkers?

7. What further support could be offered to further assist implementation?

APPENDIX D: MODELING OBSERVATIONAL CHECKLIST

Teacher:	Observer:
Observation	Explanation

Did the teacher ask students to explain their thinking?

Did the teacher use questioning to guide students' development of ideas?

Did the teacher use questioning to point out misconceptions?

Did the teacher manage classroom dissent to bring students to resolution regarding the concept under investigation?

Did the teacher use students' ideas about a concept to generalize or extend the model to a broader application?

Did the teacher ask probing questions to keep the dialog going?

Did the students work with data to draw conclusions and build ideas (or models)?

Were the students presenting their ideas?

Were the students working collaboratively to develop understanding?

Did students question each others ideas?

Did the students summarize results on whiteboards?

Other Comments: