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By

Min-Jung Bae

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ABSTRACT

USING A MOTIVATION-BASED INSTRUCTIONAL MODEL FOR TEACHER DEVELOPMENT AND STUDENTS' LEARNING OF SCIENCE

By

Min-Jung Bae

Science teachers often have difficulty helping students participate in scientific practices and understand scientific ideas. In addition, they do not frequently help students value their science learning. As one way to address these problems, I designed and examined the effects of professional development using a motivation-based instructional model with teachers and students. This motivation-based inquiry and application instructional model (MIAIM) consists of four steps of activities and identifies instructional and motivational functions that teachers can use to engage their students in scientific inquiry and application and to help them value their science learning.

In order to conduct this study, I worked with three teachers (4^{th}, 8^{th}, and 8^{th}) in both suburban and urban environments. This study consisted of three parts-an initial observation of teachers' classrooms, professional development with MIAIM, and an observation of teachers' classrooms after the professional development.

Data analysis of class observations, interviews, and class artifacts shows that there was a moderate change in teachers' teaching approach after the intervention. The three teachers designed and enacted some inquiry and application lessons that fit the intent of MIAIM. They also used some instructional and motivational practices more frequently after the intervention than they did before the intervention. In particular, they more frequently established central questions for investigations, helped students find patterns in data by themselves, provided opportunities for application, related science to students'

everyday lives, and created students' interests in scientific investigation by using interesting stories. However, there was no substantial change in teachers' use of some practices such as providing explanations, supporting students' autonomy, and using knowledge about students in designing and enacting science lessons.

In addition, data analysis of students' surveys, class observations, and tests indicates that some students from each class became more motivated to learn science when their teachers taught MIAIM based science lessons. They became more interested in science class and more appreciative of how science is related and important to their lives. In addition, students from all classes significantly increased their knowledge about scientific topics.

Several factors might have influenced the teachers' use of MIAIM: their initial teaching approaches and practices; experiences with using MIAIM in their class; the content area; and school and classroom contexts. Those aspects of MIAIM that teachers did not use may have been more difficult for the teachers to understand or may have been inconsistent with other some of their other beliefs. In addition, the changes in students' motivation and understanding of scientific ideas seemed to be closely associated with what kinds of practices of MIAIM the teachers used.

This study indicates that teachers can help students participate in scientific practices, learn important ideas, and value learning science with the help of MIAIM as a conceptual tool and contextualized support from professional development activities and curriculum materials such as worksheets and lesson plans.

To Eunhye, Jungjin, Kwangsu, parents in law, and my mother

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I would like to thank three teachers, Richard, Teresa, and Dan who volunteered to participate in this study. Without their participation, this dissertation would not have been possible. In spite of their busy schedule, they opened their classrooms to me and shared with me their work and thoughts about teaching science. Through them, I had experiences of observing American classrooms which are rare to international students. They are valuable experiences to me. The teachers were the best science teachers that I have met.

I really appreciate my family for their support and love. They are the center of my life. I would like to thank my mother and parents in law for their support and love along the way. I am deeply grateful to my husband, Kwangsu for his endless support, kindness, wisdom, encouragement, and love. He is my love and best friend, better than I deserve. I also thank my babies, Eunhye and Jungjin, for their love, smiles, and enduring the time when mommy had to study.

Most of all, I would like to thank God who created me and guided my way until now. His unfailing and endless love has always protected me. In his love and overflowing blessings, I was able to enjoy the journey through the Ph.D process at Michigan State University. To Father, Son, and Holy Spirit be all honor and glory, now and forever.

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Introduction

Problem statement

Reform efforts in science education have focused attention on how teachers can improve their knowledge and instructional practices. Reformers encourage teachers to help students understand scientific ideas and participate in scientific practices and discourses as opposed to presenting factual information in a lecture (National Research Council, 2000, 2007). Traditional science teaching approaches, which treat science in its 'final form,' leave students with a limited sense of what science is and what it means to understand or use science. Although students work on many different activities such as reading, writing, and hands-on activities, teachers do not typically use these activities to support the development of content areas in ways that are coherent and challenging for students (Roth, K., & Garnier, H. 2007). When they did present science content, they more commonly organized it as a collection of discrete facts, definitions, and algorithms rather than as a connected set of ideas. In addition, teachers often have difficulty supporting students' participation in scientific practices and discourses (Marx, Blumenfeld, Krajcik, & Soloway, 1997; Weiss, Pasley, Smith, Banilower, & Heck, 2003). One possible reason this occurs is because teachers have few opportunities to learn about reform-based teaching approaches and did not learn science in the way (Lortie, 1975).

In addition, although the reform efforts in science educations do not emphasize motivational approaches for learning science, teachers can and should help students be motivated to participate in a science learning community. Teachers' effective use of motivational strategies is important in order to increase students' understanding of scientific ideas and their participation in science practices and discourses. Furthermore, it is also necessary to help students appreciate how science is relevant and important to their lives, and enjoy their science class. However, teachers do not frequently use motivational strategies to increase students' valuing of learning school subjects and some teachers even use strategies that undermine students' motivation for learning science (Green, 2002; Raphael, Pressley, & Mohan, 2008). Many students express that science is not interesting, or not useful although some of them wanted to have jobs in science fields (Osborne, 2003, Yager & Yager, 1985). One possible reason this occurs is because teachers maybe usually do not have a chance to learn about the motivational strategies that best support students' learning (Harris, 2008) and teachers may not know what motivational strategies will be effective for their students. Therefore, teacher educators should help teachers learn about and effectively use motivational strategies as well as teach science in ways that closely align with the reform-oriented approaches of science teaching.

In order to help teachers learn about and use effective motivational approaches, they must engage in professional development. Effective professional development involves several aspects. First, teacher educators need to help teachers revise or develop their beliefs or knowledge of teaching and learning because their beliefs or knowledge influence what and how they learn at teacher education programs (e.g., Hammerness, Darling-Hammond, & Bransford, 2005; Pajares, 1992). Teachers also need to develop their knowledge about specific subject-matter content and their understanding of how students learn that content (Fennema et al, 1996; Kahle, Meece, & Sxantlebury, 2000; Wood, Cobb, Yackel, 1991). In addition, many researchers suggest helping teachers analyze cases of teaching and reflect on their own teaching (e.g., Zembal-Saul, Blumenfeld, & Krajcik, 2000; Davis & Smithey, 2009). In addition, it is important to help teachers develop professional development communities for teachers to share their ideas or coach other teachers (van Driel, Beijaard, & Verloop, 2001).

However, current research on teacher development has several limitations for understanding how to help teachers develop knowledge and practices about both motivation and instruction. First, there are few studies on developing teacher motivational strategies. While many professional development programs focus on developing teacher knowledge about instruction, they tend to be silent about how to help teachers develop motivational practices and knowledge. Fives and Manning (2005) argued that there is the lack of emphasis on knowledge related to student motivation in the frameworks about teachers' knowledge. Research on teacher understanding of diverse student needs has the potential to uncover the importance of teacher knowledge and practices for motivating diverse students to learn science but research tends to focus on cultural or social differences and equality. If teacher educators and researchers on motivation cooperate to develop professional programs, we may learn about how teachers develop motivational and instructional practices.

Second, a great deal of teacher development research reports the impacts of professional development on teacher knowledge and practice, they tend to be silent about the influence of teacher professional development on students' learning and motivation (Fishman, Mark, Best, & Tal, 2003). Few studies examine the relationships between students' understanding of scientific ideas and teacher practices (McNeil & Krajcik, 2008). However, in order to understand the effect of professional development, we need to assess students' learning outcomes or their changes in their motivation to learn in addition to teacher outcomes. This will help to develop evidence-based teacher development programs that actually result in changes among students, and will help educators understand the types of instructional and motivational practices that are effective in the classroom.

Therefore, there is a need for a research on how to support the development of teachers' knowledge and practices about science instruction and motivation, and how teacher development and practice influences students learning and motivation.

Purpose of the Study

As one way to address the need, I design and test a motivation-based instructional model and related professional development intervention for supporting teacher motivational and instructional practices in several science classes. There are two main reasons that I chose a motivation-based instructional model as the center for the intervention. First, instructional models can support coherent learning experiences that can help students build new understandings by participating in inquiry-oriented lab activities and constructing conceptual frameworks (Abraham, 1998; Bybee, 1997; Edelson, 2001). This meets the goal advocated by science education reform documents (NRC, 2007). In addition, researchers have reported the positive influence of using instructional models such as inquiry and application instructional model in teacher education programs on pre-service teachers' knowledge of teaching science, and their practices of planning and teaching science(e.g., Schwarz, & Gwekwere, 2007; Zubrowski, 2007; Zembal-Saul, 2009). Instructional models can serve as cognitive tools that enable teachers to synthesize ideas, guide their own skills in teaching science, and apply core principles of reform-based science teaching (Schwarz & Gwekwerere, 2007). They can also help teachers think about how to engage students in lesson sequences in those practices (Abraham, 1998; Bybee, 1997; Edelson, 2001; Lawson, 1995). However, existing instructional models do not usually include recommendations from motivational research. To address the issue, I incorporate motivational components into an inquiry-application instructional model (I-AIM) which synthesizes many existing frameworks for inquiry-application type lessons (Gunckel, Bae, & Smith, 2007).

The purpose of this study is to examine the effects of professional development experiences around a motivation-based instructional model on teachers' teaching approaches and practices and on students' motivation and learning in science. The suggested model used in this study is called "Motivation-based Inquiry and Application Instructional Model" (MIAIM). It focuses on 1) using scientific inquiry, 2) applying scientific knowledge to students' every day lives, and 3) helping students enhance their valuing of learning science. During the intervention for professional development using MIAIM, teachers learned about inquiry-and application-based science lessons and motivational strategies to make science relevant and interesting to students, and modified their classroom teaching materials to address some of these issues. This study investigates how teachers change their teaching approaches and practices after participating in the intervention and what effects the instructions based on MIAIM have on students' motivation and learning.

Research Questions

There were three research questions in this study aimed at addressing these issues. The first two research questions involved the influence of the professional development intervention using MIAIM on teachers' approaches and practices. The first question asked about teachers' initial approaches and practices. In order to understand the effect of professional development activities on teachers, it is necessary to understand what teacher's teaching looked like before they participated in professional development activities. In particular, I wondered what teachers' science teaching approach were. For example, did they use a traditional didactic approach to focus on presenting scientific information? Or did they use other approaches that align with reform-oriented models of instruction? In addition to teaching approach, I was interested in specific instructional and motivational practices used in their classes. Among various kinds of instructional practices, I focus on a few instructional practices relevant to promoting students' scientific practices because prior studies show that teachers have various views about scientific inquiry (e.g., Kang, Orgill, & Crippen, 2008) and that they have difficulties in helping students participate in the practices (e.g., Marx, Blumenfeld, Krajcik, & Soloway, 1997). Regarding motivational strategies, I focus on value aspects of motivational practices because teachers do not frequently use motivational strategies to increase students' valuing of learning school subjects while they use other aspects of motivational practices.

My second research question focused on changes in the approaches and practices after the intervention. I was interested in how their teaching changed after the intervention. The answers to my first two research questions lead to a better understanding of how teachers use motivation-based best practices to teach science after participating in professional development using MIAIM. In summary, these questions about teachers were:

1) What were teachers' (a) initial teaching approaches, (b) instructional practices for promoting students' scientific practices, and (c) motivational practices for helping students value learning science?

2) What changes in teachers' approaches and practices occurred after their participation in the professional development?

In order to understand the effect of professional development, we need to assess students' outcomes in addition to teacher outcomes. My last research question focused on the influence of the intervention on students' learning and motivation. Ideally, changes in teaching approach and practices after teacher development should have some positive influence on students' participation in class activities, their motivation to learn science, and their understanding of scientific ideas. In this study, I hypothesized that changes in teaching practices would influence students' motivation, especially, their valuing of learning science and their understanding of scientific ideas. I also hypothesized that changes in teaching practices and students' valuing of science would positively influence their effort in participating in class activities. The research question was as follows:

3) What effect did instruction based on MIAIM have on students' valuing of learning science, efforts to learn, and understanding of scientific ideas? What features of instruction might have played a role in these outcomes?

Contribution of this study

This study contributes to research in several domains including teacher education, motivation, and science education. First, this study looks at motivational aspects of teaching and learning, integrates knowledge about inquiry-based science teaching and motivation, and develops a motivational-based instructional model tool for teacher development. Because current instructional models do not include motivational aspects of learning, the professional development using MIAIM is a new approach to help teachers develop both instructional and motivational practices. In particular, the model stresses the importance of helping students appreciate their learning of science, which lacks in our current goals in school learning (Brophy, 2008).

Second, this study informs the teacher education community about what kinds of professional development and support can be incorporated in teacher education. MIAIM and the intervention of this study suggest one way to support teachers' practices and their students' learning in a relatively short term. Introduction of MIAIM and co-developing curriculum materials using MIAIM was helpful for teachers to use some practices for scientific inquiry, application, and motivation.

Third, the results of this study about teachers' initial teaching approaches and practices shows what happens in typical science lessons. This finding is very important because there are few studies that actually examine teachers' instructional practices in inquiry classrooms (McNeil & Krajcik, 2008) and motivational practices to promote students' valuing of learning science (Brophy, 2008). The finding regarding the changes in teachers' teaching approaches and practices also inform the community about what kinds of teaching practices can be changed though the professional development using MIAIM.

Finally, this study provides empirical evidence for relationships between teacher development and student learning. It helps teacher educators develop evidence-based teacher development programs and understand what types of teaching practices actually help students with their learning and motivation.

Overview

I provide an overview of the following chapters, outlining the study and my finding.

Chapter Two: Background-Literature and MIAIM

In chapter 2, I explain the background literature guiding my dissertation and a motivation-based inquiry and application instructional model (MIAIM) used in the professional development activities for my dissertation. This study is based on three kinds of literature—teacher learning, motivation, and instructional models. The literature review on teacher learning gives a conceptual framework about teacher development for this study and relates it to professional development. In addition, the literature review on motivation outlines what motivational principles or practices teachers should know to be able to enhance students' valuing of learning science. The literature review on instructional models explains the features of the models and provides a rationale for using instructional models in teacher development activities. The literature provided an important foundation for design the motivation-based inquiry and application instructional model, and conducting the professional development in this study.

Chapter Three: Methods

This chapter presents the research methods for this study. First, I explain the design of my study, which consists of three stages: 1) initial data collection, 2) professional development intervention, and 3) data collection after the intervention. The design was appropriate to understand how professional development activities using MIAIM affected both teachers and students. Then, I describe the participants of my study—three teachers and students from their classes—and classroom contexts. I also explain how I introduced MIAIM during professional development activities, and provide a timeline of the implementation of this study. Finally, I describe data sources and my analysis, including the analysis of the teaching approach and practices and the analysis of students' valuing of science, efforts to learn science, and understanding of scientific ideas.

Chapter Four: Findings and Discussion about Teachers' Teaching Approaches and Practices

In this chapter, I examine the influence of professional development on three teachers' teaching approaches and practices. Chapter four consists of two parts. Part I describes teachers' initial teaching approaches, including their goals in teaching science and ideas about scientific inquiry and their lesson sequences. It also describes their initial instructional practices addressing scientific practices as well as their motivational practices for enhancing students' valuing of learning science. Part II describes the results of the professional development intervention using MIAIM on teachers' teaching approaches and practices. I describe how and what features of MIAIM each teacher used in their science lessons and explain patterns in their use of MIAIM. Finally, I discuss the role of MIAIM in teacher development and reasons for individual teacher's differences in their changes of teaching approaches and practices.

Chapter Five: Findings and Discussions about Students' Valuing of Science, Efforts to Learn, and Understanding of Scientific Ideas

In this chapter, I examine the influence of the professional development on students' valuing of science, efforts to learn, and understanding of scientific ideas. First, I describe the overall change of students' motivation to learn science and student's changes in their views of whether they think science is useful, important, and interesting to them. I discuss the relationships between students' changes in their valuing of science and each teacher's use of practices in MIAIM. Second, I describe changes in students' efforts to learn science, focusing on the number of on-task students in science class and their perceived efforts in science class. I also discuss the relationship between the changes and their teacher's use of MIAIM. Finally, I report the results of student understanding of scientific ideas from the three classes and discuss student gains in understanding and teachers' use of MIAIM.

Chapter Six: Conclusion

In this final chapter, I summarize the findings and discussions in this dissertation.

I discuss the implications of this study for teacher development. I also describe the limitations of this study and directions for future research.

Chapter Two: Background-Literature and MIAIM

In this chapter, I discuss the background literature guiding my dissertation and the motivation-based inquiry and application instructional model (MIAIM) used in the professional development activities for my dissertation. This study is based on three kinds of literature—teacher learning, motivation, and instructional models. The literature review on teacher learning gives a conceptual framework about teacher development for this study and relates it to professional development. The literature review on motivation gives ideas about what motivational principles or practices teachers should know to be able to enhance students' valuing of learning science. The literature review on instructional models explains the features of the models and provides a rationale for using instructional models in teacher development activities. The literature provided an important foundation for design the motivation-based inquiry and application instructional model, and conducting the professional development in this study.

Teacher learning

Teacher learning has been described in a number of different ways (e.g. Darling-Hammond, & Bransford, 2006; Feinman-Nanser, 2008). This study is particularly focused on professional development and ways in which professional development affects teacher knowledge and practice. In this section, I explain teachers' knowledge and practices for effective science teaching and a model of teacher learning that provides a useful foundation for understanding teachers' knowledge and practices.

Knowledge and practices for effective science teaching

Effective teachers have extensive knowledge about various aspects of teaching and learning and are able to put what they know into actions. Shulman (1987) categorizes knowledge that teachers need for effective teaching. These categories are content knowledge, pedagogical knowledge, and pedagogical content knowledge. Effective science teachers have extensive knowledge about science contents and the nature of science, knowledge about teaching and learning in general, and knowledge about how to help students understand scientific ideas and participate in scientific practices and discourses. In addition, although there is a lack of emphasis on knowledge related to student motivation in the frameworks about teachers' knowledge (Fives & Manning, 2005), science teachers also should have knowledge about how to help students be motivated to learn science. These knowledge and skills help teachers solve various challenge that they face in their science classes.

As one areas of pedagogical content knowledge, science teachers should know about how to help students participate in scientific inquiry and application practices (NRC, 2007). For example, students should have central questions for investigations, collect and analyze data, and construct explanations. They also apply the knowledge to new situations. Through these inquiry and application activities, students understand and develop scientific ideas. To help student learning, teachers should have knowledge and practices to effectively support each scientific practice and organize the several class activities to help students learn scientific ideas.

In addition, teachers should know about how to help students to be motivated to learn science. This is because students' learning is not a cold, isolated cognitive process but is highly related to their motivation (Pintrich, Marx, and Boyle, 1993). Furthermore, effective motivational strategies in traditional science classrooms focusing on transmission of knowledge may differ from those in reform-oriented science classrooms. For example, the motivational strategy of focusing on test results may be effective in traditional science classrooms but not in inquiry classrooms. Therefore, there is need for clarifying knowledge and skills to motivate students to learn science in reform-oriented science classes as well as knowledge and skills regarding instructions. In the next section, I introduce a model of teacher learning that provides a useful foundation for understanding how teachers develop knowledge and practices.

A model of teacher learning

Teacher learning has been described in a number of different ways (e.g. Clarke & Hollingsworth, 2002; Darling-Hammond, & Bransford, 2006, Feinman-Nemser, 2001, 2008). There are the central tasks of teacher preparation, new teacher induction, and early professional development (Feinman-Nemser, 2001). For example, pre-service teachers need to revise their beliefs about teaching and learning, and have beginning repertoires of teaching. In-service teachers need to develop their knowledge and practices that align with the reform-oriented model of instruction. As children's learning occurs within the 'zone of proximal development' (ZPD) (Vygotsky, 1978), teachers may have their ZPD in their learning to teach. With help of other knowledgeable persons and theoretical and practical tools, teachers may be able to develop these knowledge and practices, and solve problems in teaching science.

This study is particularly focused on professional development and ways in which professional development affects teacher knowledge and practice. Important components of such a model typically include professional development activities, teacher, and enactment. Fishman, Marx, Best, and Tal's (2003) model of teacher learning is particularly useful for describing how teachers learn to teach science as they participate in professional development activities because this model clearly points out the process of ongoing teacher learning with respect to relationship among professional development activities, teachers, students outcome. Figure 2.1. illustrates their model of teacher learning.

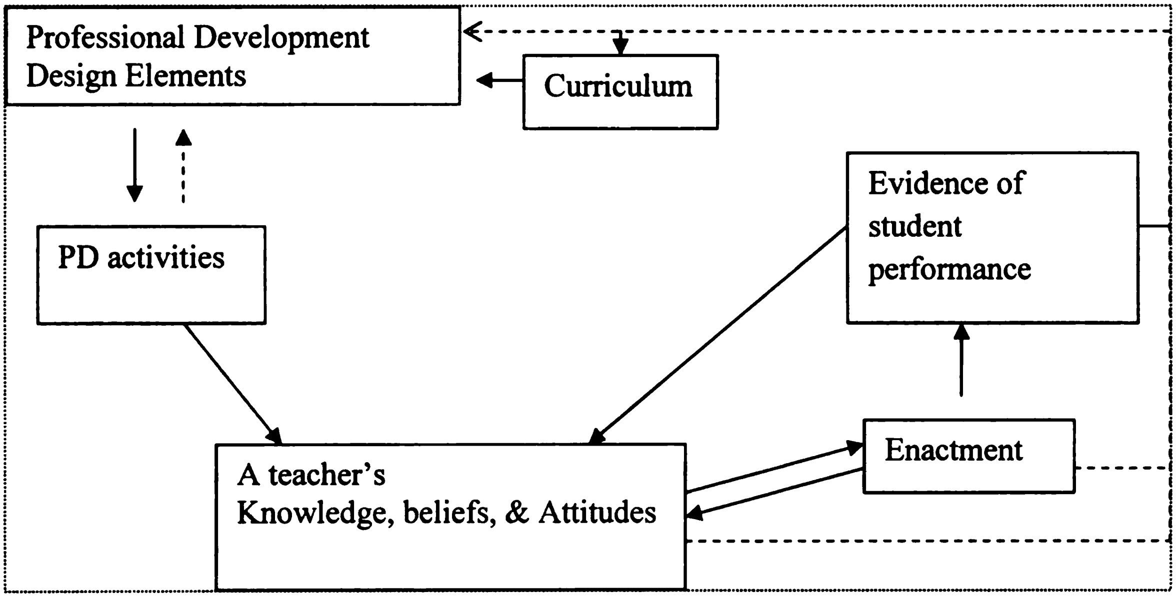

Figure 2.1. A model of teacher learning by Fishman, Marx, Best, and Tal (2003)

In the model, they explain that teachers' knowledge, beliefs, and attitudes are the aspects of teacher cognition that are affected by participation in professional development. Teachers' knowledge, beliefs, and attitudes are formed interactively with class enactment and each can influence the other. Student performance also influences teacher knowledge, beliefs, and attitudes, mediated through enactment. As they teach, teachers intuitively look to their students for feedback about the instruction. This information forms a key component of the feedback loop that shapes teachers' beliefs about their students and their own teaching (Richardson, 1996). In addition, they argue that 'curriculum' holds a central place in any model of teacher learning, because curriculum presents direction for teachers to teach in classroom. Professional development needs to help teachers to successfully teach the curriculum to students. Finally, there are 'professional development design elements.' These are the components that comprise professional development. Designers of professional development have immediate control over and are able to modify them in order to increase their impact on teacher knowledge, beliefs, and attitudes, and subsequent enactment. The authors argue that there are four primary 'elements' over which designers of professional development have control: the content of professional development, the strategies employed, the site for professional development, and the media used. These four elements can be combined in various ways to create professional development experiences for teachers.

The model of teacher learning from professional development is useful for explaining teacher learning. Teachers develop their knowledge and practices not only by participating in teacher development, but also by using and enacting what they learned in the professional development (PD) in their classes. By the continuous cycle of learning in PD activities, using what they learned in class, and reflecting what they did in class, teachers continuously develop their knowledge and practices. In addition, this model points out the relationship between teacher learning and student learning. Finding out the relationships helps teacher educators understand what changes in teaching practices actually influence student learning. This process will eventually help develop an empirical basis for design decisions in professional development rooted in evidence linking student and teacher learning.

However, this model also has three important limitations for explaining how teachers learn. Each of those limitations is important for understanding the outcomes of this study. First, this model focuses highly on teacher knowledge, beliefs, and attitudes rather than teacher practices. The authors argue, "a chief objective of professional development should be to foster changes in teachers' knowledge, beliefs, and attitudes, because these components of teacher cognition show a strong correlation to teacher's classroom practices" (p.645). Although teacher knowledge, beliefs, and attitudes are important in teacher development, changes in teacher practices should also be the direct goal of teacher development programs. This is because many studies have reported discrepancies between teacher knowledge and their practices (e.g., Loughran, 1994). In other words, teachers do not always do what they think best when teaching probably because of lack of skills, conflictions among their beliefs, or other constraints such as time. In addition, what actually influences student learning or motivation is teacher practices, such as what teachers say and do in the class, rather than what teachers know and think. Therefore, professional development activities should focus on developing teacher practices as well as helping teachers develop their knowledge (Darling-Hammond, & Bransford, 2006).

Second, this model is not clear about the importance of teachers' existing knowledge, beliefs, and attitudes for their development. The authors define teacher learning as *'changes* in the knowledge, beliefs, and attitudes of teachers that lead to the acquisition of *new* skills, *new* concepts, and *new* processes related to the work of teaching' (p.645). Although 'change' in teacher knowledge and acquisition of 'new' ideas are important, it is hard to change teacher knowledge without considering their existing knowledge. Furthermore, the authors do not mention how to use teachers' existing knowledge in teacher development. Although they assessed teachers' existing knowledge or beliefs, the primary purpose during their study was to find out the effects of professional development on teacher knowledge.

However, learning is heavily influenced by an individual's existing knowledge and beliefs and is situated in contexts (Greeno, Collins, & Resnick, 1996). Like all learners, teachers interpret new knowledge and experiences through their existing knowledge and modify and reinterpret new ideas on the basis of what they already know and believe (Feiman-Nemser, 2008). As van Driel, Bejaard and Verloop (2001) argue, "reform efforts in the past have often been unsuccessful because they fail to take teachers' existing knowledge, beliefs, and attitudes into account" (p.1). A reform project should take teachers' knowledge and practice into, and changes in these should be monitored through the project.

Finally, this model does not consider the influence of social and cultural contexts on teacher learning. Learning is situated in particular contexts where knowledge is acquired and used (Greeno, Collins, & Resnick, 1996). What teachers learn is also influenced by the social and cultural contexts. For example, when the principal of a school expect certain things like standardized test improvement or quiet classrooms his expectation can affect how teachers teach science. Teachers may put their efforts into helping students memorize scientific information rather than helping students to participate in scientific inquiry. Various settings in which teachers learn—professional development programs, schools and classrooms—enable and contract teachers' adoption and use of knowledge and practices and their ongoing learning (Feiman-Nemser, 2008).

Based on the critique, I modified the model of teacher learning (See figure 2.2.) This model showed components over three different time intervals. At Time 1, teachers interpret new knowledge and practices through their existing knowledge and practices and learn new ides and skills by participating in professional development (PD) activities. The PD activities influence what teachers learn, but what teachers already know and do influence the interaction with teacher educators during the PD activities. In addition, curriculum materials present the direction for teachers to teach in the classroom. At Time 2, teachers enact the curriculum materials in their classrooms. Through planning, enacting, assessing, and reflecting on their teaching, teachers learn how to use new practices and acquire new knowledge. The curriculum materials are used as a tool to guide their teaching. Teachers interact with curriculum materials when constructing the planned curriculum. This planned curriculum guides the teacher in co-constructing the enacted curriculum with the students (Remillard, 2005). Depending on contexts in which teachers use their knowledge, what teachers learn differs. While teachers' new practices influence students' learning and motivation, student reactions in their classroom also influence what teachers learn. Teachers look to their students for feedback about the instruction and reflect their teaching. Finally at Time 3, teachers transfer their new knowledge and practices to teach different curriculum materials. The application of the knowledge and practices is also influenced by the features of the curriculum materials, their students, and other contexts. Teachers experience ongoing learning through participating in several teaching cycle of planning, enacting, assessing, and reflecting.

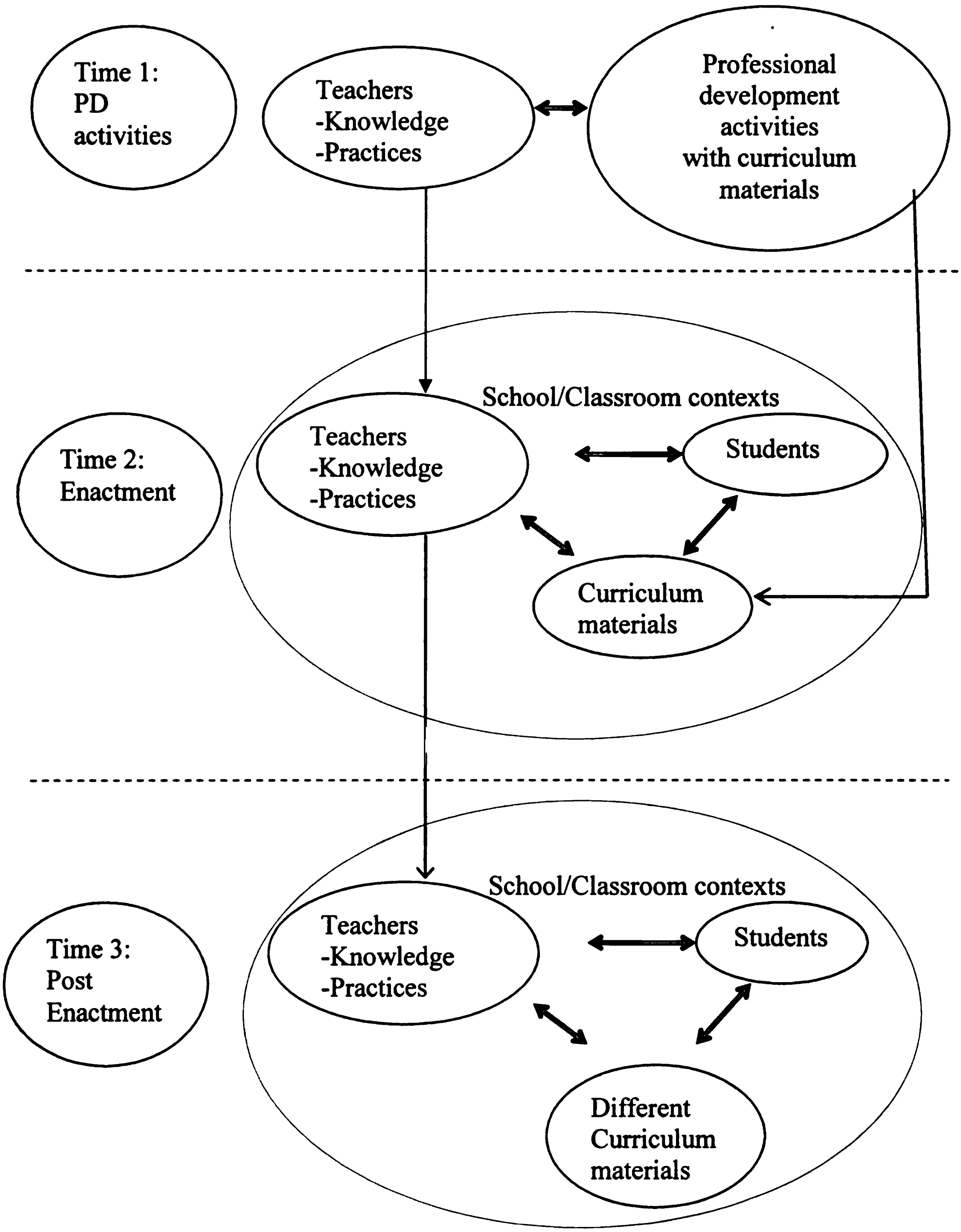

Figure 2.2. A revised model of teacher learning

While this model is useful for describing how teachers continuously learn to teach through participating in professional development and enacting curriculum materials, it does not adequately specify which teacher knowledge bases and practices should be developed. In particular, while researchers have identified knowledge and practices related to instruction such as teachers' views of inquiry, there is a need for clarifying knowledge and skills to motivate students to learn science in reform-oriented science classes as well as knowledge and skills regarding instructions. In the next section, I summarize the literature on motivation in order to explore what motivational knowledge and skills are necessary for teachers.

Motivation

This study will focus on the value aspects of motivation among three big areas of motivational research: classroom environment, expectancy, and value. Researchers concerned with the classroom environment are interested in developing classroom motivational climates and goal structures that can promote students' motivation. Research on expectancy aspects of motivation addresses topics about expectation of success or failure and concerns about social comparisons. Research on value theory focuses on answering questions about what makes a content or learning activity valuable and how we can help students appreciate it (Brophy, 1999, 2008). All three areas are important, but I argue that teacher educators and motivational researchers should help science teachers be able to enhance students' valuing of learning science. In other words, teachers should be able to help students find science interesting, relevant, or important to them. This is because helping students appreciate their learning is important in motivating them to learn science, but teachers do not frequently use practices that help students see the value in learning activities (Bae, 2007; Green, 2002). Valuing motivational practices are less found in typical classrooms than other motivational strategies such as motivational strategies to improve students' expectancy to success in a task probably because the valuing motivational strategies are related to content areas and because teachers did not have opportunities to learn about the motivational strategies at the University. In the next paragraphs, I will explain the framework of values, how teachers value science, and motivational principles to enhance students' valuing of learning science.

Framework of values

Eccles and Wigfield (1985) suggest that people participate in a task when they put value on it and expect they will succeed in the task. They suggest that subjective task value has three major components: attainment value, intrinsic/interest value, and utility value. Attainment value is the subjective importance of doing well on a task in order to affirm one's self-concept or fulfill one's needs for achievement, power, and social needs. Intrinsic/interest value is the inherent enjoyment one gets from engaging in an activity. Utility value is the perceived usefulness of a task as a means to achieve a career goal or other larger goals. In order to focus on cognitive aspects of students' motivation to learn academic content, Brophy (2004) includes the satisfaction of achieving understanding or skill mastery under attainment value, aesthetic appreciation of the content or skill under intrinsic value, and improving one's quality of life or making one a better person to the framework under utility value. This framework of three values is useful for explaining the various reasons that students learn science. For example, a student may study science because science is exciting (intrinsic value). Another high school student may take an advanced science course in order to gain entry into a certain university program which he wants to attend (utility value). One female student may not study science hard because she does not think that doing well in science is important for girls and her friends do not study it as well (attainment value).

Teachers' valuing of science

A few studies have investigated teacher knowldge and practices regarding the valuing of learning science. For example, Helm (1998) shows how experienced secondary science teachers appreciate the value of science. According to the analysis of interviews, science was important to all five teachers but they appreciated it in different ways. For example, they liked science because of the thrill of discovery, the scientific perspective in seeing the world or giving a chance to work with students as a teacher. Although Helm illustrated teachers' perceived value of science, he did not report how their views influenced thier practices, particulary how they helped their students understand the value of learning science.

Bae (2007) investigated teachers' views and practices of valuing of science through survey, interviews, and classroom observations. Analysis of classroom observation and interviews showed that teachers did not frequently communicate the values of science in class. In addition, their communication had limitations in helping students enhance their valuing of learning science because their comments to help students find science interesting or relevant to students' lives were short. This result corresponds with other research. Studies on teacher motivational practices reports that many teachers do not frequently use motivational practices in a way that helps students appreciate their learning (Brophy & Kher, 1986; Green, 2002) and that some teachers even use practices that undermine students' motivation to learn school subjects (Dolezal, Mohan Welsh, Pressley, & Vincent, 2003; Raphael, Pressley, & Mohan, 2008).

In addition, teachers do not have sufficient knowledge of the effects of motivational practices. For example, many elementary and secondary teachers try to make school subjects fun through hands-on activities, believing that this practice is effective (Zahorik, 1996; Bae, 2007). However, the strategy of just using hands-on activities, which is frequently used in inquiry classes, is not related to improving students' perception of utility value of science or their interests in science (Mac Iver, Young, and Washburn, 2002). The possible reasons for teachers' ineffective use of the practices may come from their lack of opportunities to learn about student motivation. Teachers do not have experiences learning about motivational practices at the University and want to learn about motivational practices (Harris, 2008). Therefore, teacher educators should help teachers learn motivational principles and practices that are useful to help students understand the value of science.

Motivational principles to enhance students' valuing of science

Until very recently, few studies focused on the question of how teachers can help students understand the value of school subjects and develop interests (Brophy, 2008). There are some recommendations for classroom application which are given by some motivational theories and studies. Because my study focuses on intrinsic/interest value and utility value[1], I summarize motivational principles helping students understand utility values of science or develop their interest in science.

Utility value: In order for students to understand the utility value of science, the content that teachers teach in school should be meaningful or relevant to students' lives. Meaningfulness refers to students' perception of the content's application to life outside of school (Mitchell, 1993). Relevance refers to one's perception that something is related to one's personal needs or goals (Keller, 1983). Science is useful for solving problems in students' everyday lives, understanding the world around them, and accomplishing other goals such as career goals.

Many motivational theorists have expressed the importance of meaningfulness and relevance of school subjects to students' lives (e.g., Hidi & Renninger, 2006; Mitchell, 1993). Students are more willing to engage with content that they view as relevant to their agendas and applicable to their lives outside of school (e.g., Blumenfeld, et. al., 1991; Frymier, 2002). Regrettably, classroom observation studies show that many teachers do not frequently use practices to make school subjects relevant to students (Green, 2002; Newby, 1991).

Researchers make several recommendations for framing content or learning activities to enhance their perceived relevance to students (Frymier, 2002; Keller, 1987). The recommendations include 1) stating how the learning would build on the students' existing skills; 2) using analogies familiar to the learner from past experience; 3) relating

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[1] Among the three values, in this study, I focus on intrinsic/interest value and utility value, but not attainment value. This is because the first two values seem to be more related to the scientific content than the other value.

it to their interests; 4) attempting to link content to students' needs such as the need for affiliation, power, and achievement; 5) pointing out its current or future applicability in their lives; 6) modeling enthusiasm for its applications; 7) using authentic material and activities; and 8) asking them to determine for themselves why or how the content is relevant to them.

Interest value: In order to help students be intrinsically motivated to learn science, intrinsic motivational theorists and interest theorists have given some general suggestions: 1) use classroom management and teaching styles that address students' needs for autonomy, competence, and relatedness; 2) plan learning activities that students are likely to find enjoyable or intrinsically motivating; and 3) modify the design of other learning activities to include features that will enhance the activities' appeal (Brophy, 2004; Hidi & Renninger, 2006; VanSteenkiste, Lens, & Deci, 2006).

Brophy (2004) listed the following as potential sources of intrinsic or individual interest in activities: 1) genetically-based temperament or predispositions (e.g., high-arousal people are likely to prefer active pursuits, whereas low-arousal people are likely to prefer quieter ones) 2) fun, enjoyment, 3) self-actualization potential (allows one to feel empowered or creative), 4) meaningful, satisfying (allows one to experience new understandings or take satisfaction in achieving new insights or syntheses of knowledge), 5) identification/self-projection (allows one to project oneself into situations, such as by identifying with a central character in a story, simulation, or historical text), 6) identification/assimilation to self (experience with an activity or exposure to modeling or information about it makes one want to engage in it, to learn more about it, and so on).[2]

Although some general recommendations and possible sources of interests are suggested, those recommendations and sources have not been fully realized in science classrooms (Raphael, Pressley, & Mohan, 2008) because specific practices are not suggested. In addition, there is a need for creating coherent, effective approaches that synthesize recommendations about teacher learning regarding instruction and motivation. To address these problems, this study uses an instructional model as the center for professional development activities to provide a tool for teachers to synthesize ideas about instruction and motivation for effective science teaching.

Instructional model

As I said before, this study uses an instructional model as the center for professional development activities to provide a tool for teachers to synthesize ideas about instruction and motivation for effective science teaching. In this section, I review literature on instructional models, focusing on the background of instructional models and uses of the models in teacher education programs. I also introduce one instructional model, I-AIM, to which I add motivational components in order to help teachers develop both instructional and motivational knowledge and practices.

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[2] Brophy (2004) also mentioned that relevance/utility to one's agenda has potential to increase one's interest in it.

Definition and theoretical backgrounds of instructional model

An instructional model is defined as a simplified representation of the process one might engage in and the content one might address while teaching science (Schwarz & Gwekwerere, 2007). Examples of instructional models includes the Learning Cycle Approach (Abraham, 1998), the conceptual change model (Teichert & Stracy, 2002; Minstrell, 1989), and the BSCS 5E's approach (Bybee, 1997). Each instructional model consists of several phases that help teachers sequence activities to coherent learning experiences. For example, the learning cycle approach (LCA) consists of three phases (Abraham, 1998). First, in the exploration phase, students are given experience with the concept to be developed, often involving a laboratory experiment. Second, in the conceptual invention phase, the students and/or teacher derives the concept from the data, with this usually being carried out during a class discussion. Third, the application phase gives the student the opportunity to explore the usefulness and application of the concept. Similarly, another model, the conceptual change model, consists of three phases. A teacher finds out students' preconceptions, challenges them by providing discrepant events or conflictions between ideas, and helps students integrate the preconceptions into new classroom ideas (Teichert & Stracy, 2002; Minstrell, 1989). Through lessons based on the conceptual change model, a set of concepts is replaced with another if the learner is dissatisfied with the former, and the latter has a higher status in terms of its intelligibility, plausibility and fruitfulness from the learner's viewpoint (Posner, Strike, Hewson, & Gertzog, 1982).

These instructional models has been developed and used since the late 1950s. For example, the term 'learning cycle' was used since 1950s when school science curriculum project initiated. The conceptual change model was studied after Posner, Strike, Hewson, and Gertzog, (1982) posed the model of science learning as the process by which people's central concepts change from one set of concepts to another set, incompatible with the first.

These models are based on a cognitive perspective of learning. Specially, the learning cycle approach and the conceptual change model are based on constructivism influenced by Piaget who argued that a child constructs knowledge by interacting with the environment (Ginsburg & Opper, 1979). Knowledge cannot simply be transferred to a passive receiver but is constructed and based on the learner's existing knowledge and experience. Learners reorganize or remove their prior knowledge[3] through the process of assimilation and accommodation.

Effects of instructional models on students' learning

Many studies on instructional models have reported a positive influence on students' learning while some reported no influence on students' learning. Instructional models, which focus on students' active construction of scientific knowledge, have been strongly proposed as the alternative of traditional science lessons in where knowledge is informed by teachers. In spite of their strengths, they have some weaknesses in effectively enhancing students' learning. In the next paragraph, I will describe the effects of instructional models on students' learning, focusing on two instructional models, the

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[3] For example, McClosky (1983) proposed that students' well organized misconceptions, called naïve theory, should be removed and changed by scientifically accepted knowledge. diSessa (1988) suggested that students' preconceptions, called knowledge in piece, should be restructured and reorganized.

learning cycle approach and the conceptual change model, because the two models have been widely studied in the area of science education.

Learning Cycle approach. Many studies on the learning cycle approach has confirmed that this is an effective instructional strategy with many advantages over more traditional approaches in terms of student's attitudes, scientific skills, and conceptual understanding (Abraham, 1998). For example, Bowyer's (1976) study of scientific literacy among 521 rural six grade students showed significant gains in basic process skills and content knowledge associated with exposure to the lessons based on the approach. The most important conclusion from studies using the approach is that merely providing students with hands-on laboratory experiences is not by itself enough. Laboratory activities should be used to introduce concepts so that students are given the opportunities to construct knowledge from their experiences and apply the knowledge to new situations.

However, the approach has two main limitations. First, based on largely Piagetian psychology, the learning cycle approach focuses more on individual construction of knowledge than on social construction of knowledge. Although discursive practices are expected in the second phase of the learning cycle approach, the focus is more on personal construction of knowledge developed from the data or observations in the experiments. However, because learning is both "a process of actual individual construction and a process of enculturation into the… the practices of wider society" (Cobb, 1994, p.13), teachers should not disregard the social aspects of learning science. Second, the learning cycle approach does not give any information for teachers on how to know and use student's intellectual and motivational resources in order for teachers to help students construct their knowledge and want to participate in learning activities.

Conceptual Change model. Researchers have reported mixed results of the effects of the conceptual change model on students' learning. Many reported a positive influence of the conceptual change model on students' positive motivation and their deep understanding of scientific concepts (e.g., Barlia and Beeth, 1999; Lee and Anderson, 1993; Melonie & Stracy, 2002). For example, Melonie and Stracy (2002) explore the effectiveness of the conceptual change model for a college general chemistry course. This study is focused on student preconceptions, knowledge integration, and student explanation. The experimental group explained chemistry topics at a more sophisticated level than did the control students and they also had fewer misconceptions. The number of poor performers in the experimental group was significantly smaller than that of the control group. Studies that reported positive influences argued the need for using the conceptual change model to help students construct their knowledge instead of a traditional didactic teaching approach[4].

However, some studies reported no effects of the conceptual change model on students' learning (e.g., Hellden & Solomon, 2004). For example, Helleden and Solomon

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[4] For example, Duit (1991) described the roles of students' preconceptions in the traditional classroom setting and emphasized the need for the conceptual change model. First, students' conceptual frameworks guide observations. Although demonstration experiments are very important in science and are used in classrooms, research has shown that students very often do not observe what is obvious from the scientific point of view. Second, empirical evidence does not necessarily convince students that their preconceptions are inadequate. Third, there is a tendency to "observe" only the aspects of experiments that support one's own views. Fourth, conceptions guide the information provided by the teacher or the textbook. Finally, traditional didactic instruction very often fails to guide students from their own conceptions to the scientific conceptions.

(2004) reported that there was no significant change in student's preconceptions between an experimental group, who learned science based on the conceptual model, and a control group. As the reason for the ineffectiveness, researchers criticized the conceptual change model for ignoring other aspects which can influences learning, such as social, cultural, contextual, affective, and motivational aspects (Pintrich, Marx, & Posner, 1993; Abd-el-Khalick & Akerson, 2004; Solomon, 1987). For example, Pintrich, Marx, and Posner (1993) criticized the model because it focuses only on student cognition without considering the influences of students' motivational beliefs about themselves as learners and their roles in the classroom community. They say the model fails to explain why students with the needed prior conceptual knowledge do not activate this knowledge when engaged in school tasks. They suggested that conceptual change is mediated by four general motivational constructs (goals, values, self-efficacy and control beliefs), and is moderated by a host of classroom contextual factors (task, authority and evaluation structures, teacher modeling and scaffolding, and classroom management). In other words, although many researchers agreed on the need for conceptual change to help student learning, the model did not consider other facts that may influence students learning such as social, contextual, and motivational aspects

Instructional models can support coherent learning experiences that can help students build new understandings by participating in lab activities and constructing conceptual frameworks. They have potential as the alternative to the traditional didactic science teaching approach. However, these models have limitations. They focus on individual construction of knowledge rather than social construction of knowledge. They also do not include other factors that influence student learning such as social, contextual, and motivational aspects. In addition, these models do not include the most recent recommendations about scientific inquiry practices (NRC, 2000). Therefore, in order to increase the positive effects of models on students learning, those models need to be refined, I suggest, to include motivational components, social aspects of learning, and scientific inquiry practices.

Use of instructional model in teacher education programs

Recently researchers started using the instructional models to help pre-service teachers understand how to teach science. This new tendency seems to be based on three factors—positive influence of the models on student learning, using the models as a tool to help pre-service teachers develop their ideas about and practices for science teaching, and creating coherence for the design of teacher education experiences across various communities of practices. First, although there are limitations of instructional models, the models have positive effects on student learning compared to the traditional teaching approach (e.g., Abraham, 1998, Melonie & Stracy, 2002). Secondly, those models can serve as cognitive tools that enable pre-service teachers to synthesize ideas for how to teach science, guide their own skills in teaching science, and apply core principles of reform-based science teaching (Schwarz & Gwekwerere, 2007). Teachers need conceptual and practical tools to enhance their knowledge and practices (Darling-Hammond, et al., 2005). Finally, instructional models can be used as a central framework for cooperation of several communities of practices (Zembal-Saul, 2009). In order to effectively help teachers learn to teach, it is important to give similar and repetitive messages across communities of practices that teachers participate in (Darling-Hammond, et al., 2005). For example, pre-service teachers learn how to teach inquiry-based lessons using instructional models in science methods courses, learn experiences of participating in scientific inquiry in their science courses, and observe science instruction based on the models in their field placement.

Recently developed instructional models used in teacher education programs include recent recommendations about scientific inquiry practices (NRC, 2000) and several features of pre-existing instructional models such as the learning cycle, 5Es or conceptual change. These recently developed instructional models include the argumentation framework called TESSA (Teaching Elementary School Science as Argument) (Zembal-Saul, 2009), EIMA (Schwarz & Gwekwerere, 2007), observational and planning tool (Zubrowski, 2007), Inquiry-Application instructional model (Gunkel, Bae & Smith, 2008) and model-based inquiry (Windschitl, Thompson, & Braaten, 2008). The argumentation framework called TESSA (Teaching Elementary School Science as Argument) employed by Zembal-Saul (2009) focuses the pre-service teachers' attention on authentic scientific discourse, explanation structure, and scientific reasoning and emphasizes the use of evidence to construct arguments. The author provided opportunities for the pre-service teachers to use the TESSA framework for argument construction to plan and teach a series of lessons on one scientific concept. The author immersed the pre-service teachers in an explanation-driven inquiry so they could better understand how to use this pedagogical stance to develop their students' understanding of science concepts. Schwarz (2009) used an instructional tool called EIMA (Engage-Investigate-Model-Apply) to plan lessons that incorporate scientific practices. EIMA was especially intended to help the pre-service teachers sequence their lesson activities so students could engage with real-world phenomena and use model-based reasoning to develop explanations. Zubrowski (2007) developed an observational and planning tool which describes categories of pedagogical practices related to an extended inquiry-cycle model. During the professional development project, mentors used the tool to provide effective feedback to mentees, and mentors and mentees used it for adapting existing curriculum to a more standards-based mode of instruction. Gunkel, Bae and Smith (2008) designed an Inquiry-Application Instructional Model (I-AIM) which synthesizes many of the instructional frameworks to help pre-service teachers critically analyze curriculum materials and plan and teach science lessons in ways that more closely align with reform-based models of instruction. Findings from studies on the instructional models showed that the models helped teachers 1) use reform-based criteria to critically analyze curriculum resources, 2) plan science lessons that more closely align with reform-based models of instruction, and 3) develop their views of teaching science. In other words, the studies suggest that instructional models serve as a powerful scaffold for teachers' developing, thinking, and practice.

While instructional models are useful for teachers to plan and teach lessons, the models themselves do not mention enough about students' motivation and their prior knowledge. However, good science teachers should consider students' prior knowledge, experiences, backgrounds or motivations when planning and teaching. While instructional models can give structure to a lesson, effective science teachers should think about their students. Some instructional models have components to understand the cognitive aspects of students such as prior knowledge and experiences, but fewer have components relate to student motivation. Therefore, there is a need to incorporate some motivational components to existing instructional models.

To address the problem, I chose one instructional model, I-AIM among the many instructional models for several reasons. First, I-AIM has few components to help students become motivated to learn science but it has potential to include several motivational components in the model. I will explain it in detail in the following section. Second, I-AIM includes some components related to understand students' prior knowledge and experiences. Finally, while TESSA or EIMA focus on specific scientific practices such as argumentation or modeling, I-AIM deals with general scientific practices including inquiry and application. For this reason, it can be widely used among various science teachers. In the next section, I will discuss I-AIM in order to examine the benefits and the possible limitations of the model.

The Inquiry-Application Instructional Model

The Inquiry-Application Instructional Model (I-AIM) synthesizes multiple instructional models such as conceptual change and 5Es as well as the recommendation about scientific practices (NRC, 2000). I-AIM consists of four steps and each step has its own functions to help students achieve specified learning goals. The steps and their functions in I-AIM are the following: Engage (establish a problem and elicit student ideas); Explore & Investigate (explore phenomena and explore student ideas); Explain (Develop students' explanation; introduce scientific ideas; compare to student ideas); and Apply (apply scientific knowledge to new situations) (See table 2.1.).

Table 2.1. The Inquiry-Application Instructional Model

Model Stage	Activity Functions for instruction
Engage	• Establish a Problem/Ask a Question • Elicit Student Ideas about the question
Explore & Investigate	• Explore Phenomena and look for patterns • Explore Student Ideas about the patterns
Explain	• Develop students' explanations • Introduce Scientific Ideas • Compare and revise Student Ideas
Apply	• Practice with support • Practice with fading support

This model has several benefits for student learning and teacher learning. Regarding the benefits to student learning, science lessons based on I-AIM can provide students with opportunities to participate in scientific practice, understand scientific knowledge, and use the language of science. Scientific practice is made up of interrelated cycles of inquiry and application (Anderson, 2006), and the steps of MIAIM mirror the scientific practices in many ways. The first three steps of I-AIM focus on helping students participate in inquiry practices—learning from experiences by looking for patterns across many phenomena and developing explanations for those patterns. In addition, the last step focuses on application practice—using knowledge to understand other patterns and experiences. As the result of productive participation of inquiry practice, students can construct scientific knowledge about patterns, models, and explanations, and apply the knowledge to new situations. Finally, students use the language of science (Lemke, 1990) when exploring their ideas, using evidence to justify their ideas, or comparing their ideas to scientific explanations in the second and third steps of I-AIM. Science lessons based on I-AIM have the potential to provide a rich environment where students participate in the science learner community.

Regarding benefits of the model to teachers, I-AIM can be used as a cognitive tool to scaffold teacher's learning to teach science. First, I-AIM highlights critical features of inquiry and application based science lessons that teachers might overlook. Teachers have different ideas about what inquiry is (Windschitl, 2004) and there is a gap between teachers' views of inquiry and features of inquiry reported by NRC (2000). For example, teachers did not mention the two important features of inquiry—evaluating explanations in connection with scientific knowledge and communicating explanations (Kang, Orgill, & Crippen, 2008). However, I-AIM clarifies the components of inquiry and the sequence of inquiry and application based science lessons. It can also give guidelines for planning and teaching science lessons.

Second, I-AIM gives teachers guidelines about how to take account of students' ideas and build their knowledge. Understanding students is one of the important problems of practice that teachers face (Davis & Smithey, 2009; Mikeska, Anderson, & Schwarz, 2009). Instruction that follows the model provides students with opportunities to share their ideas, then revise their ideas as they engage in new experiences. Students compare their explanations of observed patterns with the scientific explanations introduced, thus supporting students in recognizing how scientific explanations are plausible and fruitful (Posner *et al.*, 1982; E. L. Smith, 2001).

Finally, I-AIM helps teachers critically analyze curriculum materials and think about what activities they would use to support student's conceptual learning (Gunckel, Bae, & Smith, 2007). Beginning teachers tend to use hands-on activities for motivating students in class activities or make science lessons fun, but do not necessarily think about how the activities would support to help students learn specified learning goals (Kang & Anderson, 2009; Mikeska, Anderson, & Schwarz, 2009). However, lessons based on I-AIM connect hands-on experiments, patterns in data from the experiments and explanations; therefore, teachers have to think about which experiences they would use to help students find patterns that support scientific explanations.

While I-AIM has the potential to give students opportunities to participate in the science learner community and to be used as a cognitive tool to scaffold teacher learning to teach science in a way that closely aligns with the reform-based models of instruction, it does not include the research from literature on students' motivation. However, motivating students to learn is one of teachers' big concerns and teachers do not frequently use motivational practices that support students' valuing of science (Bae, 2007; Raphael, Pressley, & Mohan, 2008). Therefore, there is a need to incorporate motivational components into I-AIM in order for the model to be useful as an effective tool for teacher development and students' learning of science.

Motivation-based inquiry and application instructional model (MIAIM)

In this section, I explain MIAIM; motivational components added to I-AIM. First, I provide the rationale for why I choose I-AIM among various instructional models for adding motivational strategies. Then, I describe motivational principles and practices that can be used to help students appreciate their learning of science. Finally, I explain the steps and feature of MIAIM.

Rationale for adding motivational components to I-AIM

While I-AIM gives ideas about how to sequence activities, it tends to be silent about how to frame the activities for motivating students to participate in the activities. However, learning is situated in contexts as well as involving active construction of knowledge. Therefore creating contexts in which students are easily motivated to learn is very important in teaching science. Specifically, if students do not appreciate the goal of science learning or lack interest in the learning, they may not use their prior knowledge to understand specific learning goals (Barlia and Beeth, 1999; Pintrich, Marx, and Boyle, 1993) or legitimately participate in scientific practices.

I-AIM has the potential to be combined with motivational principles. For example, it includes an activity asking students' ideas about scientific questions, in which teachers have a chance to understand students' prior knowledge and experiences. In addition to this intellectual resource, teachers may have a sense of their students' interests in the question and connect students' personal interests with topics that they learn. In addition, I-AIM provides students with experiences with phenomena. Students' involvement in hands-on investigations or group works in the investigations is one of the sources to catch student interest (Hidi & Harackiewicz, 2000; Mitchell, 1993). Application of scientific knowledge can also give students a sense of the relevance of the topic to their lives and understand the importance of learning science if a teacher clearly and repeatedly shows how scientific knowledge applies to students' everyday lives (Pugh, 2002).

Adding motivational components to I-AIM

As part of my preparation for this study, I added motivational components to I-AIM, in particular helping students appreciate values of learning science. The motivational components are chosen based on the recent literature on value aspects of motivation and science learning. The components includes: teaching contents that have significant value, making the relevance of the topic to student's lives, organizing activities to catch and hold student's interests, supporting students' autonomy, and know and use knowledge about students. In the next paragraphs, I will explain the components.

First of all, to help students appreciate values of learning science, a teacher should teach content or use learning activities that have significant value (Brophy, in press). A teacher needs to focus on big or powerful ideas rather than individual facts to help students understand the world. The learning activity should focus on helping students acquire important scientific skills such as finding patterns or making argumentations, rather than just for fun for students' engagement, which is one of problem pre-service teachers face when they organize science lessons (Mikeska, Anderson, & Schwarz, 2009)

Second, a teacher needs to make the relevance of the topic to students explicit rather than assuming students understand it in class or in their future. As making thinking visible is useful to students' understanding of science content (Linn, 2000), making the relevance or application visible may scaffold students' valuing of learning science. For example, a teacher may explain the relevance/benefits of learning the contents to students or society, point out its current or future applicability in students' lives, or ask students to determine why or how the content is relevant to them.

Third, a teacher needs to organize learning activities to catch and hold students' situational interests as well as leveraging students' individual interests (Hidi & Harackiewicz, 2000). For as a secondary science teacher, it is not easy to find out all his students' interests and to tailor the lecture to each student's interest. In that case, he may plan learning activities that students are likely to find enjoyable or intrinsically motivating, and modify the design of other learning activities to include features that will enhance the activities' appeal. For example, he may use themes relating to topics widely viewed as interesting (animal or human life, injury or death, and so on), use stories to allow students to project themselves into situations, such as identifying with a central character in a story.

Fourth, a teacher needs to use classroom management and teaching styles to address the students' needs for autonomy (Deci & Richard, 2000; Vansteenkiste, Lens, & Deci, 2006). The more students perceive learning activity as autonomous rather than extrinsically controlled, the more they experience intrinsic motivation. Students can perceive a learning activity as autonomous or self-determined by adopting values of the task as personally important or integrating the values into their coherent sense of selves. A teacher may help students to increase their autonomy by providing choices, minimizing extrinsic performance pressures, or encouraging students to solve problems in their own ways rather than insisting on a single method.

Finally, teachers should know their students and use this knowledge about students in their lessons. Knowing about students' experiences can help teachers link their students' ideas with those in the content area and help students become more invested in knowing the outcome. Knowing about students' interests or values can help a teacher link their interests or values with those of science.

Motivation-based inquiry and application instructional model (MIAIM)

Motivation-based inquiry and application instructional model (MIAIM) brings together essential elements of scientific practices (NRC, 2000) and motivational components to scaffold students' appreciation for science learning. Table 2.2 shows steps and activity functions for instruction and motivation in MIAIM.

In the Engage stage, a teacher establishes a problem that gives purpose to students' study and elicits students' ideas about the problem. The problem and the learning goals of the overall lessons should have significant value. Because the engage stage is the beginning of the overall lessons, a teacher needs to help students have positive attitudes towards upcoming learning activities (Burden, 1995). To do so, a teacher needs to make the relevance of the topic to students explicit and catch students' interests in the topic. While eliciting students' ideas about the problem, a teacher may know students' prior experiences, knowledge, or interests, and connect their interests to the topic that they learn (see Appendix 1 &2 for specific instructional and motivational strategies).

In the Explore and Investigate stage, students explore phenomena and explore their ideas. They are provided with experiences with scientific phenomena and have a chance to find patterns in the experiences and construct explanations for the patterns. In the Explain stage, students explain their ideas about their patterns and explanations, and a teacher introduces scientific ideas. Students compare their explanations for observed patterns with scientific explanations introduced, and revise their ideas when the scientific explanations are plausible and fruitful (Posner et al., 182). In those two steps, which are the middle of the overall lessons, a teacher needs to hold students' attention and interests (Burden, 1995). In addition, he needs to set up learning activities in a way to support students' autonomy.

Finally in the Apply stage, students use newly-developed ideas to explain similar phenomena in new situations. Cognitive apprenticeship (Brown, Collins, & Duguid, 1989) is used to provide students with practice applying new explanations in both familiar and less familiar contexts. While helping students apply scientific ideas to new situations, a teacher should help students understand the role of science in their lives or society, and realize affordances of participating in science learning activities. These efforts may help students enhance their valuing of learning science and develop positive attitudes toward science class.

Through these four steps, MIIAM systematically presents the components of scientific practices and motivational components to scaffold students' appreciation for science learning. Therefore, it can help teachers plan and teach science lessons in ways that closely align with reform-based models of instruction. It also helps teachers effectively use motivational strategies to help students understand the values of learning science and participate in scientific practices.

Table 2.2. A motivation-based inquiry and application instructional model

Model Stage	Activity Functions for instruction	Activity Functions for motivation
Engage	• Establish a Problem/ Ask a Question • Elicit Student Ideas about the question	• Understand relevance of topic to students' lives • Catch students' situational interests
Explore & Investigate	• Explore Phenomena and look for patterns • Explore Student Ideas about the patterns	• Support students' autonomy • Hold students' attention and interest
Explain	• Develop students explanation • Introduce Scientific Ideas • Compare and revise Student Ideas	
Apply	• Practice with support • Practice with fading support	• Understand the role of science

Chapter Three: Method

Design

In order to determine how professional development activities using MIAIM affected teachers' teaching approaches and practices and their students' learning, I used a design-based research approach (Barab & Squire, 2004; Cobb, Confrey, DiSessa, Lehrer, & Schauble, 2003; Design-Based Research Collective, 2003). The design-based research approach is developed for understanding learning and teaching through the design and study of learning environments. My study focuses on creating teacher education learning environments with the goal of better understanding the development of teachers' reform-based teaching practices and their influences on students. The design-based research approach is appropriate for this study because (1) the purpose of this study is not only to determine whether the intervention around MIAIM worked, but also to investigate why and how the intervention worked and did not work and what components of MIAIM seemed to have the greatest effect, and (2) a researcher collaborates with teachers to incorporate MIAIM into teachers' science units.

I designed MIAIM and professional development activities and conducted the interventions with three teachers. This study consisted of three stages. In the first stage, teachers taught one or two units without any intervention. Data from this stage provided me with an understanding of each teacher's existing approaches and practices, and student features. In the second stage, an intervention stage, the teachers participated in the professional development activities. I introduced MIAIM and helped them incorporate this into their lessons during the intervention. In the final stage, the teachers taught other units. Data from this stage provided me with an understanding of the intervention's effects on teachers and students.

In this study, I had two roles. During the intervention stage, I served as a teacher educator to help teachers develop science teaching practices. However when teachers taught science in their classrooms before and after intervention stages, my role was that of an observer. I only observed and recorded the happenings in the science teachers' classrooms.

Participants

Teachers

Two 8^{th} grade science teachers and one 4^{th} grade elementary teacher participated in this study. I recruited them by searching for experienced or recommended science teachers who use or want to use various reform-based instructional strategies in their classrooms. Experienced teachers were selected because they already possessed skills for classroom management, leaving time to focus on the promotion of the value of learning science. Michigan State University (MSU) science education faculty members suggested several possible teachers, and I also knew some teachers through my prior study on teachers' motivational strategies. I contacted multiple teachers to inquire whether they would like to incorporate a new instructional model into science units or learn more about motivational strategies. Three teachers agreed to participate in this study. Two 8^{th} grade teachers had been students of one faculty member at MSU and the other teacher who had participated in a professional development program designed by MSU faculty members. All three teachers were similar to one another in terms of years of experience (6 to 9 years) but showed variation in their backgrounds related to science and professional development experience, school contexts, and student features (see Table 3.1. for summary of participant demographics). Therefore, the case studies of the three teachers can provide information about the nature and success of the intervention across settings. Next, I describe each teacher and characteristics of school for this study.

Table 3.1. Participating teacher demographics

Teacher	Richard	Teresa	Dan
Gender	Male	Female	Male
Grade Level	8	8	4 and 3
Experience	9 years	8 years	6 years
Settings	Suburban	Urban	Urban
# of total students in class	25	31	23
Ethnicity of most of Students	78%-White	45% Black 36% White	42% White 33% Black
% eligible for free or reduced lunch	25%	71%	54%

Richard teaches 8th grade science in a suburban middle school serving students in 7th and 8th grade. He had taught science for nine years since receiving his bachelor's degree at the local university. He had not participated in professional development programs on scientific inquiry or motivation. However, he took classes about educational technology for his master's degree although he did not finish it. His school had been worked with faculties at the local university for three years on the study of reading strategies and understanding texts. So, he said that he tried to do some of that.

The school in which Richard taught is located in one of the more affluent residential neighborhoods in the city. Public records indicated that only 25% of the students in the school were eligible for free or reduced lunch. This school's students were approximately 78% White, 9% Black, 1% Asian, 7% Hispanic, 1% American Indian, and 4% other. He taught four science classes a day and the science class that I observed included 25 students. When I observed him, he was teaching physics and chemistry.

Teresa teaches 8th grade science in a middle school serving students between 6th and 8th grade. The school was very close to the neighborhood she grew up, which is why she wanted to teach there. She has taught science for eight years in the school since she received her bachelor's degree at the same local university. In contrast to Richard, she had experience participating in a professional development program related to scientific inquiry for a couple years. The program was called PI-CRUST, which stands for "professional inquiry communities for reform-based urban science teaching"(Richmond, 2002). The program focused on helping teachers learn about science content and inquiry, students' understanding, standards-and research-based science teaching and assessment, and exemplary science curricula. In particular, it gave opportunities for teachers to learn about scientific content that they would teach, to participate in scientific inquiry, and to observe inquiry oriented teaching strategies. In that program, Teresa participated in developing curriculum materials for inquiry and implemented them in her classes.

The urban middle school in which Teresa taught is located in a mid-sized Midwestern city. Public records indicate that 71% of the students in the school are eligible for free or reduced lunch. This school's students were approximately 36% White, 45% Black, 4% Asian, 14% Hispanic, and 1% American Indian. In this sense, the socio-economic status and ethnicity of Teresa's students are different from those of Richard's students. She taught four science classes a day and the science class that I observed included 31[5] students. When I observed her, she was teaching biology and earth science.

Dan teaches a 3rd and 4th grade split in an elementary school serving students between 1st and 5th grade. Because his 4th grade students numbered less than 20, he had to teach both 4th and 3rd grade students in one class in the school year of 2008-2009. He had six years of teaching experience at the elementary level and received both his bachelor's degrees and master's degrees in education at the local university. Before becoming a teacher, he worked in biology laboratories at the local university. He also had experience participating in the same project that Teresa participated in. The project supported him in standards-based, inquiry-oriented professional development.

The urban elementary school where Dan taught was located in the same mid-sized Midwestern city as Teresa's school. Public records indicate that 54% of the students in Dan's school were eligible for free or reduced lunch. This school's students were approximately 42% White, 33% Black, 6% Asian, 17% Hispanic, 1% American Indian and 1% other. His class included 23 students (15: 4th graders and 8: 3rd graders). When I observed him, he was teaching earth science and physics.

In summary, each teacher taught science for six to nine years. They were different from each other in background, school context, and student characteristics. Richard taught science in a suburban school, but Teresa and Dan taught science in urban schools. The two urban school teachers had some experiences of participating in a project that supported them in standards-based and inquiry-oriented science teaching. Richard and Teresa started their teaching after they graduated at the local university like many

[5] In the fall semester of 2008, there were 31 students, but in the subsequent semester, there were 33 students.

other teachers, but Dan began to teach after working as a research scientist. He had more experiences in, and knowledge about, science than other elementary teachers. The various features of the teachers gave me a chance to investigate how different teachers used MIAIM differently or similarly.

Students

A total of 55 students from the teachers' classes agreed to provide data for this study. They were 18 of 25 students from Richard's class, 16 of 31 from Teresa's class, and 21 of 23 from Dan's class. I observed them during classes, collected their classroom artifacts, and assessed their motivation and understanding on the unit that each teacher agreed to incorporate MIAIM into. In addition, I conducted interviews with five to six students from each class. Based on their judgment on the level of their student's motivation to learn science, teachers suggested the students whose levels of motivation varied between high, medium, and low.

Classroom contexts and typical lessons of the three classes

Richard taught four science lessons a day and the class that I observed was his first class hour of the day. He wanted me to observe this class because the students participated in class activities more than those from other classes. Students were on time and were relatively quiet when he talked to the whole class.

Richard adopted a science curriculum developed by Holt Science and Technology. His science lesson varied in structure from day to day but included several activities to address two or three learning goals in one lesson. The activities included students' reading and writing, experiments with scientific materials, reviews of scientific ideas, and class discussion. Every student had their own book and Richard gave them reading or writing assignments using concept maps or worksheets. He also gave them opportunities to do as many experiments as possible. Whenever I observed his teaching on scientific methods and physical change, his students had time to work with scientific materials although the time to do experiments was sometimes short (about 10 minutes). He also reviewed science ideas at the end of every unit and did class discussion.

Teresa taught four science lessons and one social study lesson a day. The participating students from her class learned science in their first class hour in the fall semester of 2008 but their fifth class hour in the spring semester of 2009. In addition, a few students came into the class in November 2008 when there was a schedule change in the school. Students were quiet when she explained scientific ideas. However, the class was noisy at the beginning and end because students were not on time, there was a morning assembly in the fall semester, and she distributed or collected science folders.

Teresa did not adopt one specific curriculum. She used worksheets and activities from several books and from the internet. Her typical lesson started with a review of science ideas that students had learned the day before. Then, she introduced an activity for the day and shortly described what students would do. There was only one main activity for a day such as writing, computer investigation, modeling activities, and teacher explanation. During the main activity, students usually followed the direction of each activity described on a worksheet and wrote their answers to the questions on it. In the case of internet investigations, she and her students followed each question addressed on the computer or worksheets. They wrote their answers about predictions, patterns, or explanations. At the end of the activity, she did not give students opportunities to read their answers but rather had students submit their worksheets.

In Dan's class, there were 23 students, one intern, and one elderly 'grandfather' as well as a teacher, Dan. Dan taught science and the intern watched his teaching. At the end of the fall semester 2008, the intern taught one or two science lessons, but I did not observe her teaching. When Dan instructed students in front of the classroom, the intern usually sat down in one place but during group activities, she helped individual groups. Students sat in four groups of five or six students that included both 3rd and 4th graders and male and female students. During class activities, students in each group worked together but also individually wrote their answers to Dan's questions. The grandfather did not participate in class activities but just sat in one corner of the classroom.

Dan adopted a science curriculum developed by Biological Science Curriculum Study (BSCS). He used some activities in the books but also designed his own lessons because "investigating the earth science" by BSCS was originally designed for 3rd graders and it did not include activities to teach learning goals for 4th graders. His typical science lesson consisted of his introduction of an activity, a group activity, and individual writing. When class started, he introduced an activity for the day. He showed how to do the activity at the front of or in the middle of the classroom where materials were set up. After describing the activity, he called one student's name from each group, who then brought activity materials to his/her group. Then, he talked about who would do what in the activity and students followed his direction. During group or individual activities, he and his intern went around the groups and asked students to do their work or helped them. More than 20 or 30 minutes of a one-hour science lesson were spent performing activities including observing, collecting data, and writing answers. At the end of class, he sometimes asked students to read what they wrote but other times finished the class without students' sharing their writing.

Intervention for professional development

I held two to three meetings with each teacher in his/her classroom to introduce MIAIM and help them incorporate it into their science units. These meetings occurred after I observed their science lessons about six to seven times when each teacher almost finished teaching one or two units. Although there was some variation among teachers, the meetings consisted primarily of three different types of endeavors: (1) discussing teachers' prior teaching approaches and practices to promote students' understanding of science ideas, especially though using inquiry and application activities, and students' motivation to learn science (2) my explaining MIAIM focusing on features of each step and motivational principles, and (3) helping teachers incorporate MIAIM into their science lessons.

To understand teachers' initial teaching approaches and practices, I asked several questions about their own goals for teaching, instructional practices to achieve the goals, views of inquiry and applications, and practices to address scientific practices. In addition, I asked about motivational strategies and how they valued science. I also asked about their specific teaching strategies to understand what I observed during their science classes. Talks with teachers helped me find out their views and practices for teaching science and how their practices might have been similar or different compared with practices in MIAIM. It is important to clarify teachers' prior views and practices in order for them to compare theirs with new ones, reorganize or develop their views and practices, and understand how new ones are plausible and fruitful (Posner, Strike, Hewson, and Gertzog, 1982).

In addition, I explained MIAIM focusing on features of each step and motivational principles. To justify the steps of MIAIM, I talked about the nature of science and definitions of scientific inquiry and application, using the experience-patterns-explanation (EPE) framework by Anderson (2006). In particular, I discussed the difference between school science and scientists' science[6] in order to explain the importance of doing inquiry lessons. For example, I said that traditional school textbooks include many explanations and theories but provide a few data to support the theories. Therefore, students learn many explanations without many experiences with phenomena. However, that is not what science really is. Scientists have constructed explanations through several experiments. Teachers also said how some of their lessons fit with the EPE framework. Because the EPE framework is also introduced in Michigan High school Content Expectation, which teachers should refer to, I explained that MIAIM is theoretically based on the framework.

I also discussed that EPE framework itself did not provide teachers with specific guidelines about how to plan and teach science lesson where students can engage in scientists' science. I said that to help pre-service teachers to plan these science lessons, some researchers in MSU designed an instructional model which explain specific step of lesson that teachers and students need to follow. Then, I explained four steps of MIAIM

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[6] Providing experiences with phenomena before offering explanations and making the patterns in the experiences explicit distinguishes scientists' science from traditional school science (Anderson, 2006; Sharma & Anderson, 2003).

(Engage, Explore & Investigate, Explain, and Apply) and functions of each step for instruction. In particular, I focused on the importance of establishing a central question for investigation, finding patterns, helping students revise their ideas with scientific ones, and applications because teachers sometimes did not frequently do in their science lessons. In order to help their understandings about MIAIM, I gave documents about EPE frameworks and description of MIAIM (Table 2.2. & Appendix 1) and example lesson plans based on MIAIM. (See appendix 2 for one example lesson plan).

Then, I discussed the importance of teachers' use of valuing motivational practices. I explained some of valuing motivational principles to help students find science interesting, relevant, and meaningful (see Appendix 3 & 4) and effects of motivational practices. For example, I said that providing a rationale of doing some activities was helpful for undergraduate students to more actively participate in class activities and that providing examples of using scientific concepts in everyday lives was helpful for students to more frequently use those concepts (Pugh, 2002). After the discussion, I provided an example of how the principles are incorporated into inquiry and application lessons (Appendix 2).

Finally, I helped teachers incorporate MIAIM into their science lessons. I tried to engage the teachers in cognitive apprenticeship of planning and teaching science lessons (Collins, Brown, and Newman, 1989). I showed example lesson plans based on MIAIM to model the use of it in planning and teaching (See Appendix 2 for an example lesson plan). I used two example lesson plans. One lesson plan about electricity was for a 4th grade unit and the other lesson plan about the periodic table was for an 8th grade unit. Then, I provided coaching as teachers planed science lessons. I talked with teachers about their lesson plans or curriculum materials and how to incorporate MIAIM into their lessons. For example, I suggested that teachers help students to find patterns in data by themselves or establish central questions for investigations at the beginning of hands-on activities. I also suggested specific components or strategies of MIAIM that might seem to be relevant to their lessons. In the next paragraph, I will give more explanation about how I interacted with each teacher.

Richard and I talked how to make a lesson about periodic table to be more inquiry based. I suggested that he help students find patterns in several elements by themselves. After my suggestions and explanation of the feature of MIAIM, Richard made a new lesson plan for atoms and the periodic table and asked me whether his lesson plan would include similar features of MIAIM. Although his lesson plan included activities for students to find patterns in several elements in the periodic table, it included few motivational strategies to help students value their learning. To motivate students to learn, he planned to use games or telling importance of learning science for high school. I suggested that he relate atoms and the periodic table to students' everyday life. He suggested that we do some research about use of elements in our home. Then, he revised his lesson plan and included several activities to help students find relevant to their lives such as class discussion on the use of elements in our lives and students' research on elements in daily home products.

Dan talked about how he had taught an electricity unit for previous years and showed worksheets that he had used. I talked with him about how the sequence of his inquiry activities would be better able to match the goal of MIAIM. For example, because his previous year's worksheets included only materials, procedures, and some results, I suggested that he add a big question for a hands-on activity. I also suggested that he help students find patterns in data. Based on our discussion, he revised his worksheets. Regarding motivational practices, he said that he would show some pictures related to blackout but he did not plan to use other specific motivational strategies. Therefore, I suggested that he use some pictures of people's lives without electricity and use a story to make a context for investigation about electricity. He revised the story to make the story more specific and interesting to his students. For example, he wrote that his students would go to Vietnam to find treasure because one of his students was from Vietnam. He also added some questions at the end of the story to ask students to think about how to make bulbs light up.

Teresa showed some curriculum materials that she used previous years but she did not talked in detail about how she used them and how she planned to teach during our meetings for professional development. One of the reasons for it was that she had to develop new curriculum materials because her focus of teaching topics had changed based on the changes of objectives in Michigan Grade Level Content Expectation. She used to teach history of plate tectonics but she did not have to do that anymore and she just had to teach what happened as the results. In addition, she was required to teach only clarifications and effects of volcanoes and earthquakes different from her previous years. Therefore, one week or two days before her teaching, she briefly told the topics of her lessons and what methods she would use such as internet investigation, or modeling activities. I asked her to use specific components or strategies of MIIAM when she taught specific lessons. For example, I asked her to follow all steps of MIAIM when she said that she would do her first inquiry-based lesson about earthquakes. I asked her to help students find patterns in data. Regarding motivational practices, I also asked her to have a class discussion on why learning some topics such as volcanoes and earthquakes are important to know.

Finally, I phased out my support. With Richard and Dan, I almost stopped my scaffolding after the meetings for professional development. However, with Teresa, because she did not frequently use several aspect of MIAIM in her lessons about plate tectonics after the meetings for professional development, I asked her to use some MIAIM practices in brief conversations during school and over email when she taught earthquakes and volcanoes. After I asked her to use MIAIM a couple times, however, I phased out my scaffolding.

Implementation of this study

This study took place during the school year of 2008-2009. Before the intervention, I collected initial data from each teacher's classroom to understand their teaching and obtain background information about their students. It took two to three months for me to collect the initial data for each teacher. The introduction of MIAIM and helping teachers to use it took about two weeks. Finally, each teacher taught another science topic after the intervention and I collected data about teachers and students to examine any effects of the intervention on teachers and students. It took around two to three month to collect post-intervention data with each teacher. Table 3.2 summarizes the time line and teaching topics for the three teachers.

Table 3.2. Time line and teaching topics for the three teachers

		Before intervention	During intervention	After intervention
Richard	Unit Topic	Scientific methods & physical change		Chemical change (Atoms, periodic table, acids and bases)
	Time	Sept.-Oct. 2008	Oct. 2008	Oct.-Dec. 2008
Teresa	Unit Topic	Genetics & Structure of the earth		Plate tectonics (Plate tectonics, earthquakes, volcanoes)
	Time	Sep.2008-Jan.2009	Jan.2009	Jan.-Mar.2009
Dan	Unit Topic	Land forms		Electricity
	Time	Sep.-Oct.2008	Oct.2008	Nov.2008-Jan.2009

Because of different schedules, the topics that they taught and the timeline for the intervention and data collection were different among the teachers. Richard taught scientific methods and physical changes for two months before the intervention and taught chemical change for two months after the intervention. Teresa taught genetics and structure of the earth for three months before the intervention and taught plate tectonics for two and a half months after the intervention. Dan taught earth science focusing on erosion for two months before the intervention and taught electricity for three months after the intervention.

It took a longer time to collect data from Teresa's class than from the other two classes for several reasons. First of all, because of the students' low participation in my study and a schedule change which changed members of classes, it took about 6 weeks for me to get parental consent forms from her class. In addition, she had unexpected surgery in November, 2008 and I could not observe her teaching for three weeks. Finally, she had to teach other aspects which were not related to science in her classes. For example, in her science class, her students did a test to find out their interests for their future jobs and sex education for one week before the winter break. During these events, she did not teach science and therefore, it took roughly three months for her to finish teaching the first two units.

Data Sources

I used several data sources to address my research questions including interviews with teachers and focus students, classroom observations, lesson plans, curriculum materials, students' reflection notes, pre- and post-motivation surveys, and pre- and post-tests to assess student's understandings of scientific ideas. In the following paragraphs, I describe data sources for teachers and students.

Data sources for teaching approach and practice

In this study, 'science teaching approach' refers to the way that teachers present science in a class as well as their beliefs and understandings of teaching science. It is similar to 'teaching orientation', used by Grossman (1991) and Magnusson, Krajcik, and Borko (1999), which means the set of teacher beliefs and knowledge that guides teachers' goals and methods for teaching science. However, science teaching approach is different from teaching orientation in that it also includes patterns in teachers' actual teaching such as how they organize several activities to accomplish their goals.

'Teaching practice' is defined as skills, strategies, or repertoire of classroom enactment (Hammerness et al., 2005). Among many instructional practices to promote students participation in scientific inquiry and application practices, I focused on five instructional practices, which are important features of MIAIM: (1) ask a question that provides a sense of purpose to the student's study in the beginning of units or lessons, (2) provide experiences with phenomena, (3) make patterns explicit, (4) provide explanations, and (5) apply scientific knowledge to new situations. In addition, I focused on four motivational practices or principles to promote student's valuing of learning science: (1) make the relevance of a topic to students' lives explicit, (2) catch and hold students' situational interests, (3) support students' autonomy, and (4) know one's students and use the knowledge

To address my two research questions about 1) teachers' initial teaching approaches and practices before the intervention, and 2) changes in these approaches and practices after the intervention, I analyzed several data sources including teacher interviews, classroom observations, and class artifacts.

Interviews. I conducted four interviews with each teacher. I conducted the first three interviews before introducing MIAIM. When I mention 'pre-interviews' in my result section, it refers to the first three interviews. Then, I conducted a final interview with each teacher when he/she finished one unit of teaching after the intervention. I call the final interview 'post-interview' in my result section. Each interview lasted between 30 and 90 minutes. All interviews were audio recorded and transcribed. I used open-ended questions and probes as guidelines to invite the teachers to share their experiences and tell their stories related to teaching science. These semi-structured conversations illuminated teachers' goals, experiences, practices, and understandings related to teaching science.

The first interview took place at the beginning of the school year before the teachers participated in the intervention for teacher learning. The purpose of this interview was to get to know the teachers and to explore ideas about teaching science. I asked questions about teachers' experiences of teaching, experiences with professional development, their schools and goals for teaching science. I talked with them about units in which they wanted to incorporate a new instructional model for my study.

The second and third interviews took place when each teacher had almost completed teaching their one or two science units. The purpose of these interviews was to explore teachers' initial teaching approaches and practices. The interview questions examined teachers' own goals for teaching, instructional practices to achieve the goals, views of inquiry and applications, and practices related to inquiry and application-based lessons. In addition, the questions examined teachers' motivational strategies and how they value science. I also asked about their specific teaching strategies to understand what I observed during their science classes.

The final interview took place when each teacher completed teaching another science unit after they had participated in the intervention. The purpose of the interview was to explore changes in teachers' teaching approaches and practices after their experiences for teacher learning. First, I asked questions similar to those I asked during their second and third interviews. For example, I asked again about their goals in teaching science and their definitions of inquiry lessons to find out whether any changes occurred in their understandings or practices in teaching science. In addition, the final interview questions asked about specific activities or episodes happened in their classes. I probed the rationale for including the activities or specific practices that they used. Second, the interview protocol included questions to probe teachers' ideas about how they used MIIAM and how it worked in their classes. Finally, the interviews ended with teachers' recommendations to MIAIM in order to be revised and used for other teachers' learning such as pre-service teacher education programs. Appendix 5 shows all interview questions.

Observation. I observed each science teachers' instruction between 12 to 14 times prior to and after intervention. Before intervention, I made five to seven visits to each teacher's classroom approximately once a week. The purpose of these observations was to document teachers' instructional and motivational practices and to understand their teaching approaches. After the intervention, I made six to seven visits to each teacher's classroom approximately once or twice a week. The purpose of these observations was to understand their general teaching approach and their practices. More specifically, I looked at how their teaching was similar or different compared to MIAIM, how they incorporated MIAIM into their lessons after the intervention, and how students responded to teachers' messages or actions.

Before each observation, I tried to talk with each teacher about class activities of the lesson. Dan and Richard gave some information about the lessons and what they did before the lessons. Teresa did not have much time to give this information when I observed her lessons before intervention but she was able to give it when I observed her lessons after intervention. During the observation, I made field notes and video-and audio-taped each teacher using one video camera and two audio recorders. The teacher carried one audio recorder. I set up the video camera at the back of the classroom to capture the teacher as well as students. During small group activities, the video camera was focused on one group of students. After the observation, I tried to talk with each teacher about his or her thoughts about the lessons.

Class artifacts. Teachers' lesson plans and curriculum materials were collected to obtain information about teachers' practices.

Data sources for students' motivation and understanding

'Motivation to learn' is defined as an enduring disposition to value learning as a worthwhile and satisfying activity, and thus to strive for knowledge and mastery in learning situation (Brophy, 1987). Students who are motivated to learn science value their learning of science and work hard to understand science knowledge or master scientific practices because they think that participating in scientific activities is worthwhile and meaningful. In this study, I hypothesized that changes in a teacher's instructional and motivational practices may influence on students' valuing of learning science as well as their understanding of science ideas. In addition, I also hypothesized that students' enhanced valuing of learning science may influence their efforts to learn science. These efforts may also influence their understanding of science ideas.

I obtained multiple data sources about students including observations, surveys, interviews, and pre-and post-tests. I used a survey and interviews to measure students' valuing of science. To measure students' efforts to learn science I used a survey and observed their on-task behaviors. Finally, I measured students' understanding of science ideas through pre-and post-tests.

Survey on students' valuing of science and perceived efforts. The survey to assess students' motivation was administrated prior to and after the unit in which teachers incorporated MIAIM. The survey included questions about how students value science. The questions measured five specific values of learning science: everyday related utility value of science, job related utility value, importance of science, personal interest in science (interest value in science from a personal perspective) and situational interest in science (interest value in science or science class from a situational perspective). In addition, the survey also measure students' perceived efforts to learn science in class.

The survey consisted of Likert-scale items on a 7-point scale and open-ended questions (See appendix 6 for all questions). Likert-scale items were adapted from previous studies (Eccles, O'Neill and Wigfield's, 2005; Mac Iver, Young, and Washburn's, 2002; Mitchell's, 1993). Of total 16 items, there were one item for job related utility value, two items for everyday related utility value, four items for personal interest, five items for situational interest, two items for importance of science, and two items for their efforts during science class. One sample item was, "What I learn in science class is useful for my life outside of school" and students responded to the item with 1 indicating "Strongly disagree" and 7 indicating "strongly agree."

Scores from several items within each scale were inter-correlated and they were averaged into a single score for each scale. For example, there are four items to measure students' personal interests in science. The scores from these four items were inter-correlated highly enough, they were averaged into a single score for personal interest (Alpha=.795). For the other scales, the reliability was also generally high (Alpha=.591

for everyday related utility value; Alpha=.993 for importance of science; Alpha=.910 for situational interest; and Alpha=.992 for perceived importance. However, regarding the scale of job related utility value, there was only one item to measure the scale. Because there was only one item, I could not calculate the reliability though using Alpha, but the correlation of students' scores from the pre-and post-survey was high (correlation=.53, $p<.001$) and so, the item seemed to be reliable to measure student's views of how science is useful for their future jobs.

In addition, the survey included four open-ended questions in order to obtain qualitative data about students' valuing of science and their use of scientific knowledge in their everyday lives. One example was "Do you think science is useful? What parts of science are useful to you? Why? What parts of science are not useful to you? or why not?" A post-survey also asked students to respond in writing about their perception of the changes of their motivation to learn science. Appendix 6 shows all questions used in the survey.

I collected and analyzed 15 students' pre- and post-surveys from Richard's class, 17 students' surveys from Dan's class, and 10 students' surveys from Teresa's class. From Richard's class, 15 of 18 participating students completed the pre-survey and 18 students did the post-survey. From Dan's class, 20 students of 21 participating students completed the pre-survey and 17 students did the post-survey. From Teresa's class, 11 of 16 participating students completed the pre-survey and 15 students completed the post-survey. However, only 10 students completed both pre-and post-surveys in her class.

Observations. Before and after the intervention, I observed students' on-task behaviors in their science class. While I made field notes on the features of class activities and teacher's teaching practices, I checked the number of students who were on-task in class. Every 10 to 15 minutes or when class activities changed, I scanned the class and noted what students were doing, determining the proportion of students who were on task. For example, when students talked with nearby students about something that was not related to the work or played with experimental materials, I judged them as off-task. I calculated the percentage of on-task students from every class and then, I calculated the average percentage of on-task students from each teacher's class prior to and after the intervention in order to understand how MIAIM instructions influence students' efforts to participate in class activities. In addition, whole class discussions also were recorded to understand what students said in response to their teachers' messages in class.

Focus student interviews. I conducted pre-and post-interviews with 17 students from three classes before and after the unit in which teachers incorporated MIAIM. Six students were from Richard's class, five students from Teresa's class, and six students from Dan's class. Each interview lasted 10 to 20 minutes. All interviews were audio recorded and transcribed. I used open-ended questions and probes as guidelines to invite the students to share their experiences and tell their stories related to learning science. These semi-structured conversations elicited students' ideas about their motivation to learn science, experiences in science class, and their ideas about good science lessons. I also asked some questions about their responses to the questions in the survey. The post interview also included question about their ideas about their changes of motivation to learn science, reasons for the changes, and their perception of their teachers' teaching approaches. Appendix 7 shows the interview questions.

Pre-and post-test. The tests to assess students' understanding of scientific knowledge were administrated prior to and after the unit in which teachers incorporated MIAIM. Because teachers incorporated MIAIM into different science units, students from each class took a different test. Richard's students took a test on chemical change. The test to assess student understanding of scientific ideas form Richard's class included 10 questions about atoms and periodic tables (9 multiple choice questions and one open-ended question) (See Appendix 8). The test used in Teresa's class had 6 open-ended questions about plate tectonics (See Appendix 9). The test used in Dan's class had 10 open-ended questions about electricity (See Appendix 10). I designed the test items for this study based on questions from books used in the class or tests that each teacher had used to assess their students' understandings of science ideas.

The total test score from each class was obtained by summing the number of points obtained on each item. Because the maximum scores were different across the three tests, the scores were reflected as percentage correct, where the number of points obtained was divided by the number of possible points on the test, and subsequently multiplied by 100. Therefore, all test scores were reported on a 0% to 100% scale. For example, the mean score of the pre-test from Dan's class was 3.8 out of 10. The score was divided by 10 (the number of questions), and then multiplied by 100. Therefore, the average score was 38% of correct.

I collected and analyzed both pre- and post-tests of 15 students form Richard's class, 19 students from Dan's class, and 15 students from Teresa's class. From Richard's class, 17 of 18 participating students took the pre-test and 16 students did the post-test. From Dan's class, 21 students of 21 participating students took the pre-test and 19 students did the post-test. From Teresa's class, 15 of 16 participating students took the pre-test and 15 students did the post-test.

Data Analysis

Teaching approach and practice

To address my first two research questions about teachers' teaching approaches and practices before and after the intervention, I generated and used both emergent and theoretically-driven coding schemes to analyze several data sets. First, I developed and used a theoretically-driven coding scheme based on the features of MIAIM to understand teachers' teaching practices. This analysis was needed to find out how they used some aspects of MIAIM in their science classes after the intervention.

MIAIM has several important instructional features. First, science instruction should include an Engage stage activity that establishes a central question for investigation (Reiser et al., 2003; Rivet & Krajcik, 2004; E. L. Smith,2001). This activity should come near the beginning of hands-on activities. Second, in the Explore and Investigate stage activity, teachers should provide experiences with phenomena, such as giving students opportunities to collect and analyze data. The experiences should be appropriate for target learning goals and teachers should help students find patterns in the data. Providing experiences with phenomena before offering explanations and making the patterns in the experiences explicit distinguishes scientists' science from traditional school science (Anderson, 2006; Sharma & Anderson, 2003). Third, teachers should provide students with opportunities to develop their own ideas about patterns, provide scientific information, and compare student ideas to the scientific ideas introduced. Finally, teachers' sequences should engage students in the practices of application (Anderson, 2006) by providing students with opportunities to use their new understanding in new contexts (Brown, Collins, Duguid, 1989).

In addition, MIAIM also includes important motivational principles or practices. First, science instruction should include some activities in the beginning of the unit that help students understand the relevance of topic to their lives. It helps them understand how science is useful in their everyday lives and help them perceive the learning activity as supporting their autonomy. Second, teachers should design some activities that are able to catch and hold students' situational interests. Third, a teacher needs to use classroom management and teaching styles to address students' needs for autonomy (Deci & Richard, 2000; Vansteenkiste, Lens, & Deci, 2006). Finally, a teacher should know their students and use the knowledge about students in their lessons. Table 3.3 shows the analysis focus of this study.

Table 3.3. Teaching practice analysis focus

	Analysis Foci
Instructional practices	Establish a central question Provide experiences with phenomena Make patterns explicit Provide explanations Apply scientific knowledge to new situations
Motivational practices/principles	Make the relevance of the topic explicit to students Catch and hold students' situational interests Support students' autonomy Know one's students and use knowledge about the students

When I analyzed data from class observations, I looked at class activities to understand whether and how teachers used practices that met the intent of MIAIM. I checked the instances of using each practice and compared the differences of the instances before and after the intervention. In addition, I also compared the features of using specific practices before and after the intervention.

For example, I analyzed whether teachers asked a central question for a subsequent laboratory activity. If they did, I looked at how they did, such as whether the question was too short or difficult for students to understand. I figured out whether the questions were understandable to students based on what students said after their teacher asked the questions. If teachers did not pose a central question, I looked at what they did at the beginning of laboratory activities. Teachers tended to explain procedures or materials of the activities to help students engage in the activities. I compared the instances of asking a central question for following investigation activities before and after the intervention.

As another example, I will also explain how I coded teacher practices during one science lesson. In the science class, a teacher and students completed chapter review on physical change. I coded the activity as teacher provided explanations. Next, a teacher introduced a lab activity such as, "You will make a temperature and time data table." Without posing a central question for the lab, he explained procedures of the lab. I coded the introduction of the lab as a teacher did not establish central question for an investigation. Then, students measured temperature of ice by minutes and made a data table. I coded the activity as "a teacher provided experiences with phenomena."

Regarding motivational practices, I coded this lesson as using a hands-on investigation under the category of catch and hold students' situational interests.

Second, I also developed and used an emergent coding scheme to find out teacher's general teaching approaches. While the analysis of data with the lens of MIAIM was useful to understand the changes in teachers' practices after the intervention, it had limitations in showing the big picture of their teaching approach. Therefore, I looked at data from class observations and interviews from the perspective of teachers rather than a researcher and tried to understand and made an account about each teacher's general teaching approach (Simon & Tzur, 1999). I focused on how they presented science in class; how their understandings of and goals in science were connected to the way that they present science; and how instructional and motivational practices that they used were related to another. I analyzed activities of a lesson, the sequence of the activities, and their apparent functions in a lesson. Then I tried to find patterns in each teacher's use of class activities, and compared the patterns with what they said during interviews. Throughout the analysis, I tried to understand teachers' initial teaching approaches and changes in their approaches after the intervention.

Students' motivation and understanding

To address my third research question about what effect the intervention had on students' motivation and understanding, I analyzed surveys, observations, and interviews as well as pre-post tests. I used dependent t-tests to analyze the changes in student responses on their valuing of learning science and their perceived efforts during class between the pre-and post-survey. The average number of students' on-task behaviors from the three classes prior to and after the intervention was compared. I also developed an emergent coding scheme to analyze responses on open-ended questions in the survey, and interviews to examine changes in students' valuing of learning science and their reported reasons for the changes.

In addition, I used dependent t-test to understand changes in students understanding of scientific ideas in the pre-and post-test, finding out how much students understand scientific explanations on the unit, and what mis-conceptions they had before and after learning about the unit.

In order to validate findings of this research, I triangulated multiple data sources. I also checked inter-rater reliability. A second independent researcher coded part of data for teachers' teaching practices and for students' valuing of learning science on the open-ended questions in surveys. The initial reliability was 82% agreement. We discussed the discrepancies and the agreement on coding reached almost 100% after the discussion.

Chapter Four: Findings and discussion s About Teachers' Teaching Approaches and Practices

Part I: Teachers' initial teaching approaches and practices

My first research question asked: What are teachers' (a) initial teaching approaches, (b) instructional practices for promoting students' scientific practices, and (c) motivational practices for helping students value learning science? To address this question, I draw on data analyses of class observations and interviews with the teachers. After describing teachers' approaches, I describe characteristics of instructional and motivational practices.

Teaching approaches

Analysis of class observations and interviews indicates that the teachers had different initial approaches for science teaching. Richard used a combination of didactic and hands-on approaches for teaching science. He tended to focus on providing scientific explanations to students rather than helping students develop explanations through participating in scientific practices. Although he used many hands-on activities, he seemed to use those activities primarily as motivational and instructional tools to help students understand scientific ideas. Teresa used a combination of didactic and inquiry approaches. In some lessons, she lectured on scientific information, but in other lessons, she gave her students opportunities to develop explanations using data. To motivate students, she made some efforts to relate science to student's interests or lives, and used models or simulations. Finally, Dan used an inquiry approach for teaching science. He tried to present science in his class in a way "as scientists do" their research. He tried to help students both understand scientific explanations and participate in scientific practices, although his lessons did not include many features of inquiry lessons. Dan used fun aspects of class activities to help students learn science. In the following paragraphs, I will explain the teachers' approaches in detail. In order to understand each teacher's teaching approach, I will also report features of their instructional sequences and motivational practices used in their lessons.

Richard's teaching approach

` He used a combination of didactic and hands-on approaches for teaching science, which typically consisted of book reading, laboratory activities, lecture, and class discussion. During pre-interviews, he said that he tended not to give a lecture at the beginning of teaching a new topic but asked students to read books. However, because the text book he used included information about scientific explanation, students seemed to be given scientific information by the books. Then, he gave students chances to do lab activities to "interact with what they read before" if he could find hands-on activities to support students' reading. Because students were already given information through books, his teaching approach was different from an inquiry approach in which students develop scientific explanations through participating in scientific activities such as collecting and analyzing data. The following interview excerpt illustrates his typical teaching approach.

Richard (R): I do very little lecture with notes. Very little. We do a lot of class discussions, demonstrations….

R: Usually I have them do, like if it's a typical unit plan, I'll do some reading, a lab, some vocabulary and a quiz or test. ....

Interviewer (I): So students read some textbook and then they do some labs?

R: Mmm hmm.

I: The reading gives them some basic information?

R: Right. Then, often times with that information I'll have them organize a concept map…….there's other text organizers that we use. Basically to get background information so that when they do the lab they have …………for it.

I: So after reading books or something, the students do labs. Is the purpose of it understanding what they read before?

R: Mmm hmm. Understanding what they read before and interacting with what they read. It's not interacting at the same exact time, but they do get a better understanding of what they should have read.

Analysis of his class activities shows that his teaching approach was a combination of didactic and hands-on activities. Of four topics that he taught before the intervention, he usually gave explanations first and then helped students understand knowledge through laboratory activities. For example, when he taught phase change of matter, he and his students did a class discussion on phase change. He asked several questions about phase change and how to interpret graphs on the three phases of matter. After confirming students had some understanding of it, he had his students measure ice temperature while boiling it and make a graph about time and temperature as a way of demonstrating explanations about phase change. The following excerpt was from a class discussion on graphing, which showed students already understood phase change prior to the lab activity.

Richard (R): This graph, many of you have seen this graph before, which we will check ourselves today. What is the boiling point of this substance?

Students: 80 degree

R: What is the melting point?

Students: 20.

R: How do you know from this graph, its boiling point is 80?

Student: because at the 80 it is flat.

R: He said boiling point is flatted up. And why not 20? You are right. But why is boiling point is not 20?

Student: Because the boiling point is the higher one.

R: So, 20 is once it freezes

R: Which state is present at 30 degree point?

Students:

R: State. Solid, liquid or gas?

S: liquid

After describing scientific explanations, Richard provided an opportunity for students to have an experience with the phenomena of the phase change of water. Table

4.1 shows the sequence of activities in a lesson about phase change and how it matches the steps of MIAIM. Although he provided a laboratory activity, this lesson did not fit MIAIM for several reasons. First, the sequence of providing explanation and experience was opposite with the sequence of MIAIM. Second, he did not address a central question of the laboratory activity at the beginning of the lesson and students' ideas about phase change of water were not elicited. He introduced the activity by mentioning that students would make a data table. There was no Engage step in the lesson. Finally, although he said during class that students would "find pattern of phase change regardless of beaker size or amount of ice", he did not give students opportunities to compare results to find patterns in data from different experiment settings. Instead, he asked students to use knowledge to make a graph. He said, "when you finish, add phase change, where phase changes and it lost energy or gain." In other words, he focused on helping students understand knowledge by participating in laboratory activities rather than creating explanations with evidence generated by data collection.

Table 4.1. Sequence of activities on a lesson about phase change from Richard's class

Activity Description	MIAIM step
Teacher and students corrected chapter review on physical change.	Explain
Students did a lab about ice temperature and phase changes. They measured temperature of ice by minutes and made a graph.	Explore

In another lesson about the scientific method, he gave explanations about five steps of the scientific method and then had students do hands-on investigations that engaged them in demonstrating those five steps. During the investigation, he had his students follow each step of the scientific method to investigate a phenomenon of interactions of different liquids. The purpose of using the hands-on investigation seemed to help students reinforce knowledge about the scientific methods. In the curriculum materials distributed in the class, he wrote, "The colored solution lab is an investigation in which you will reinforce the use of the scientific method and gain a better understanding of each of the steps in the method. You will use your flow chart to keep track of what you did for each step in the method." Before the class, he also introduced the lesson to me such as "I had them made flowcharts about scientific methods. They have to write all steps here and how what they do in this lab would be matched with the methods." In order words, he used the hands-on activities as the tool to help students understand the knowledge about scientific methods that he explained.

Regarding motivational practices to enhance students' valuing of learning science in his science class, he had an attitude that it was hard to help students understand why learning science was worthwhile or important to them. It depended on topics where he could provide real life examples. He pointed out that it was a challenge to help students to understand why physical and chemical changes were important to learn. He said,

> Physical science, in my opinion, is one of the harder branches of science to try to incorporate into their 'why I have to learn it' attitude. It's hard to say..............you need to understand what the difference is between a physical and chemical change. It's hard to get them to say, "Oh yeah, I see why." So that's a challenge. I used to teach seventh grade science, which is more earth science, a little bit of physical. But some of the earth science, you can really get into why you need to understand why thunderstorms, tornadoes,

hurricanes....how it affects our everyday life. But as far as some of the topics of physical and chemical changes, it's harder to get them to see that.....Not much......[It is] sometimes a little bit easier to apply to the real life situations.

To help students view science as worthwhile and to help students participate in class activities, he seemed to use two kinds of practices. First, he talked about the importance of studying science for future jobs or from a scientist's perspective. Second, he tried to make science activities fun or interesting using games, hands-on activities, demonstrations, or giving choices in activities.

First of all, he talked about how science was important for their future. During interviews or class discussions, he showed that he had tendency to persuade students to study or learn science because the learning would help them get a job or they would use the knowledge in the future. For example, during the interview, he stated:

> Sometimes some of the kids ask why do we need to know this. Well, maybe you won't, but maybe you will. So it's important to learn as much as you can, because you never know when you're going to use what you learned. I try to give the example of my opinions when I was growing up, thinking, "oh, I don't have to learn this," and then further on, actually using what I learned that I thought I wouldn't have to know. It doesn't always get through.

In the interview, he also said that he told students to learn science as much as they could, because the learning may be helpful in their future although they may not find the reasons for studying science in the moment. He gave a similar message to students during class. In the class, he told to students that they should learn science because science was related to many jobs and they might get those jobs in the future. The following excerpt is his class discussion.

> Richard (R) : Say, I'm teaching you something that you really don't want to know about. 'Why do I have to learn this? What do we learn this for?' Well, the branches of science I had...kind of a secondary motivation. This helps you see that it's not just earth science. Not just life science, not just physical science. There's all these branches off of that. All those branches have jobs, careers. You know what career you're going in? You know for sure, 100%, positive, absolutely? No way it's going to change? Got it? Trust me, it may change. It's great to know what you want to do, but you're idea might change. I didn't know I was going to be a teacher until I was in college.
>
> .....
>
> R: But I didn't know I wanted to be a teacher. I thought I wanted to be in the medical field like a radiologist.
>
> Student: Do you ever want to switch to math?
>
> R: Switch to math? No, I like science. I also thought about going into golf pro management, managing golf courses. Giving golf lessons and things like that. They have a program for that at Ferris State.
>
> Student: Are you good?

R: Am I good? I can golf. I can play. I thought about that and my first year I went in 'no preference.' I started taking some college courses. I took a packaging course. You know what packaging is? Boxes, plastic, making the bottles – you know you look at these bottles and you see a recycle – LDTE. You know what LDTE stands for? I started learning about plastics and materials and finally got interested in core science. I learned all the different types of plastics in my packaging course and that leads into what branch of science? As I started taking more courses, I thought about teaching. I thought about lessons and thought, "oh, I could've done that better than so and so." I kind of thought that way in school, so I was kind of somewhat already training to be a teacher by thinking like that. Then I got to college and realized that and that's why I'm a teacher. Why am I telling you all this? Because these branches of science – you say, "why do I have to learn this?" – you never know. You might be in a branch of science someday in that field working as your career.

In the class, he tried to give the message that science would be meaningful to students because it could help them to get a job in the future. In addition, as the reason to study science, he told importance of some activities from a scientist's perspective. For example, he told students that measurement in science was important "to communicate some data". He also asked students to write down the procedure of their experiments because "experiments should be duplicated" and "if you don't have procedures written down, other scientists cannot believe you." The following is the excerpt about class discussion on the reason for writing exact procedures:

Richard (R): you can write step by step list what you will do [in your experiment]. OK? Why do you do?....

R: You don't have to that specific such as with right hand, but what you need is to make sure, experiments should be duplicate. …you exactly write what you do in your lab…. Why is that important? Anyone know?

Student: If it is published, others can do it.

R: there you go. If it is published, another group of people like scientist… You have proved something or you have discovered something. . If you don't have the procedure written down, other scientists cannot believe you. You cannot do it again and you cannot prove it. So, you discover it, you have procedure for it for it can be done again. The importance of the same procedure written down in your lab. Any other questions?

Second, he tried to make science activities fun and interesting, using games, hands-on activities, demonstrations, and so on. During my observations, he showed several demonstrations and had students participate in hands-on activities. Although the activities sometimes only lasted 10 minutes, students had a chance to work with scientific materials in every class that I observed. The reason for using demos or hands-on activities was to make science fun as well as to help students to understand scientific information. His complaint about his students revealed that he used hands-on activities for motivational reason. He told me that although he used hands-on activities more than any other teacher in his school, his students asked him, 'Do more fun things like other teachers.' In order words, he related fun things to hands-on activities.

In conclusion, Richard used a didactic and hands-on approach to teach science. He tended to focus on providing scientific explanations rather than helping students construct the knowledge by themselves through participating in scientific practices. He provided explanations first and then gave experiences. Although he provided students with opportunities to do laboratory activities, the purpose of the activities was to better understand scientific information they had read or heard and to make learning science fun and interesting. Regarding motivational practices, he had an attitude that it was hard to help students understand why learning some science topics was worthwhile or important to them. He tended to focus on using fun activities or telling importance of science for future jobs. Hands-on activities worked as a motivational and instructional tools to help students understand scientific ideas, which would help students get jobs in their future rather than help their every day lives.

Teresa's teaching approach

Teresa used a combination of didactic and inquiry approaches in her class. First, her teaching approach had some features similar to traditional school science—transmitting knowledge and practicing of using the knowledge to prepare for tests. In the beginning of the school year, she taught her students how to answer questions in MEAP test. She showed example questions from last year's MEAP test to demonstrate the formats and structures of the test. She said, "I had told them that we were going to go over the questions from last year's…I told them that we would go over it so they would get used to the formats and the structure, particularly the essay questions. They [questions] often confuse them [students] because of the format. They [students] think they're going to have to answer one of these and they have to actually do both."

In addition, she focused on helping students understand scientific terms and vocabularies. In the first week of the school year, she explained scientific language and structures, including prefixes and suffixes. She said, "Today we're working on different words and prefixes and suffixes. I think a lot of times kids are intimidated when they see the words.................like if they see 'ology' on the end of a word, it means study of.." She also had found out definitions of important vocabularies of the units from books. Students' works on vocabulary were graded. She used worksheets for student to use the vocabulary terms such as 'inherited trait' and had a review of terms or scientific explanations at the beginning of each lesson.

In class, she presented science as factual knowledge. She gave scientific explanations and definitions prior to allowing students to conduct experiments. For example, when she taught density, she explained that, "density is the ratio of mass over volume" and wrote its formula on a board. Then, she showed a rock which floated on water and one object that she could change its volume. The rock was considered less dense or denser depending on the volume of the water. Finally, she distributed a worksheet which asked students to calculate densities of four unknown liquids. Masses and volumes of the liquids were given and students were requested to write formulas as well as their densities. Then, students determined the order in which the liquids have settled in a tank. When students calculated densities, she went around and helped students calculate them and also gave calculators. After finishing the work, students gave her their worksheets to be graded. The sequence of this class was 'presenting information, showing examples, and practicing using the explanation' and it was very similar to the nature of didactic lessons which consists of explanation, possible verification lab, and students practice (Magnusson et al., 1999)

However, Teresa also used some features of an inquiry approach similar to reform science teaching methods such as asking a question, analyzing data, and constructing scientific explanations or model. She defined inquiry as "the starting point of what happens. And it goes toward the reality." By reality, she meant "the truth" and she said she helped students to arrive at the truth by "visualizing, modeling, and analyzing data." According the evidence from interviews with her, she used inquiry lessons as a "hook" to motivate students to learn science and to help students understand scientific explanations rather than focusing on helping students to participate in scientific practices. She did not do inquiry lessons frequently. She said that she did inquiry lessons once or twice a unit and each inquiry lesson was one hour long.

Before the intervention, I observed three inquiry lessons where she used the terms 'investigation' or 'lab' when introducing the lessons to students in class. Table 4.2 describes the lessons including sequence of activities from her class. The lessons included some inquiry-based features such as asking a central question for the investigation in the beginning of the lesson, observing and analyzing data, and constructing models or explanations. For example, in a lesson investigating the structure of the earth, she asked the question, "How do we know about layers of the earth?" In order to answer the question, she showed computer simulations about the paths of P and S waves on a model of an earth on web-page. After students observed the paths taken by

P and S waves through the earth, she asked questions about layers of the earth based on the evidence of P and S waves. She and her students constructed scientific explanations on layers of the earth using the evidence of P and S waves and she summarized them.

However, in the three inquiry lessons, students did not have opportunities to observe first-hand and find patterns in the data. Instead, the lessons were about making models or interpreting computer simulations to help students understand scientific models and explanations. In addition, the lessons were highly structured and guided by the teacher or curriculum materials in that she posed a central question, students followed scripted procedures provided by the teacher or worksheets, or the teacher showed computer simulations with one computer.

Table 4.2. Sequence of activities from three separate lessons from Teresa's class

Lesson	Activity description	MIAIM steps
A modeling activity on traits	Teacher established a central question of why brothers from same parents look different.	Engage
	Students did a modeling activity on traits of three generations and solved analysis questions in worksheets.	Explore
	Teacher summarized answers to the analysis questions	Explain
Investigation of the structure of the earth	Teacher established a central question of "How do we know about layers of the earth?"	Engage
	Students observed the paths taken by P and S waves through the earth shown on Internet Web-page. They analyzed the paths and draw a model of structure of the earth	Explore
	She and her students constructed scientific explanations on layers of the earth using the evidence of P and S waves	Explain
Astro-adventure investigation	Teacher established a central question of " how the earth will be different if we change the geologic features of the earth"	Engage
	Teacher showed computer simulations about the effects of movements of mantle, crust on earth environment.	Explore
	Teacher and students talked the effects shown in the simulation and teacher told what scientists said about it.	Explain

To motivate students to participate in the lessons, she said that she used two kinds of practices—relating science to students' interests or lives, and using models or visualizing science. First, during the pre-interviews, she stated that she tried to relate science to their lives, but sometimes it was hard for her to do so because some topics were abstract. As she said, during my observations, she gave real-world examples to students. For example, she told how her husband and her brother-in-law looked different and asked "how brothers from same parents look different?" She also talked about Italian dressing, in which oil and vinegar were not mixed, and asked students solve problems of density. However, her comments on real-world examples were infrequent and short. In addition, she did not give students opportunities to think about their own experiences related to the topics.

Second, she said she used visual models to make the learning of science realistic. She said, "The other thing is try to do as much with visual models as I can. They have a real hard time reading something and having it make sense. Not only with comprehension problems, but the fact that we're talking about spatially is such a large scale, it's really abstract to them. It's hard to make it real." The three inquiry lessons from her class were about using models: a modeling activity on traits, making a model of the structure of the earth, and seeing the cause and effects of a geologic feature of a model about the earth.

In conclusion, Teresa used a combination of didactic and inquiry approaches to help students understand scientific explanations and catch students' interests in science classes. She sometimes used a traditional didactic approach but other times used an approach with features of inquiry. Models played a role in her teaching to help students understand abstract science content and catch their interest. By relating science to student's lives and interests, she tried to motivate students to learn science but had difficulties in doing so in some topics.

Dan's teaching approach.

Dan used an inquiry approach for teaching science. He tried to present science in his class "as scientists do" their research. He tended to minimize providing basic information before doing experiments and had students participate in scientific practices such as making predictions and hands-on data collections and observations. It seemed that his purpose of using hands-on activities was not to verify scientific information already given to students, but to help students "explore and try to get some information from that [the investigation]." He identified his students in class as scientists by saying "you are scientists" or asking them to do something "as scientists do." In other words, his teaching approach of helping students participate in scientific practices had similarities with the goals of reform-oriented teaching methods.

Analysis of his class activities showed that his general teaching approach was inquiry. Table 4.3 provides a summary of main activities from his classroom. Of the seven class periods he taught, the lessons show that students participated in scientific practices such as data collection, predictions and comparisons in five classes [class #1, 2, 4, 5, and 6 in the table 4.3]. Students participated in arguing their scientific explanations in another class [class # 7 in the table], and finally in the other class, his students applied what they learned into new situations [class #3 in the table].

Table.4.3. Summary of class activities from Dan's class

Class	Activity number & Name	Activity description
1 & 2	Tumbler experiment	Students observed stones and made predictions about what would happen to the water, stones, and sand after three weeks of continuous tumbling. Three weeks later, students observed the stones again and wrote why their stones changed.
3	Magazine activity	Each student cuts out a landform from a magazine and describes their landform.
	Globe game	Students tossed a globe to another student and where their left pinky finger lands, they told what landform it was on.
4	Sandblaster	Students observed and drew a picture of card A and B after they had blown through a straw over the sand gently or strongly. Students wrote their answers to the questions on differences between the two cards and what caused the sand get to the glue on the paper
5	Glacier modeling activity	Teacher and students co-designed an experiment to make ice glacier move. Students measured the movements of the ice glacier once an hour about 4 times. On the next day the ice was melt.
6	Stream studies	Students observed each "stream" of water in two different angles and described it on their paper. Teacher asked students label the diagram on a stream where sources, mouth, bank, and channel of the stream are
7	Science talk	Students argued each other on a question of how rocks change.

His inquiry lessons showed a pattern of providing basic information, data collection, and construction of scientific explanations although there were some variations among the lessons. For example, to help students understand the erosive process, he designed and enacted an experiment with stones and a tumbler (class #1&2 in the table). After the teacher explained what sedimentary rock was, he asked students to collect stones and described the features of their stones. Then, he established a central question of what would happen to the water, stones, and sand after three weeks of continuous tumbling. He made students predict the answer to the question. After three weeks of tumbling, the teacher showed the stones again and had students write comparison paragraphs on the 1) water, 2) stones, and 3) sand. This investigation had several features of inquiry-based lessons including asking a central question of the investigation, making predictions, observing and analyzing data, and developing explanations.

In spite of his efforts to help students participate in scientific practices as scientists do, his lessons did not include some important features of inquiry and application. Figure 4.1 shows the frequency of using each component of inquiry and application in the seven classes. While students spent ample time observing what was happening to sands, rocks, or ices, Dan did not consistently address the central questions of the experiments prior to their observations. Although he asked students to compare and contrast results, he did not always focus on making patterns across experiences explicit.

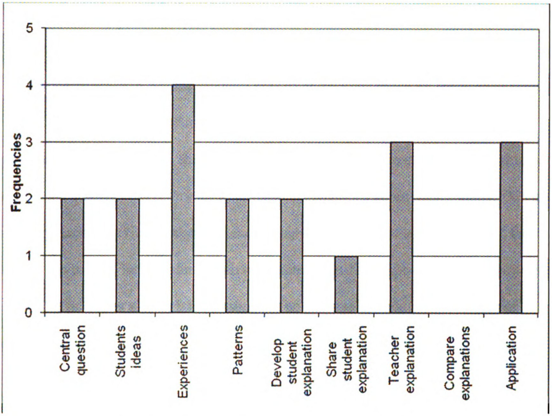

Figure 4.1. Frequencies of scientific practices used in Dan's class

To motivate students to participate in his lessons, he used hands-on activities, games and humor, and authentic materials. In addition, he thought the inquiry approach itself was motivating to students. He explained that inquiry gives students ownership. During the pre-interviews he expressed, "It's something that they take ownership of. That's one of the things that I see that is really important for inquiry. Inquiry is students take ownership of their own work and that's why it works so well. Because it's theirs." In addition to using inquiry activities, he tried to make the activities fun by using humor when introducing the activities. Students laughed during class and said, "cool" during experiments.

In summary, the teachers had different initial teaching approaches. Richard had a combination of didactic and hands-on approaches. He focused on providing scientific explanations rather than helping students construct the knowledge by themselves through participating in scientific practices. Teresa had a combination of didactic and inquiry approaches. In some lessons, she gave scientific information directly, but in other lessons, she gave her students opportunities to develop explanations about data. Finally, Dan used an inquiry approach. He presented science in his class in a way "as scientists do" their research. He tried to help students both understand scientific explanations and participate in scientific practices although his lessons did not always include many features of inquiry lessons. Regarding motivation, all teachers tended to using hands-on activities to make science fun and interesting. Although how to use lab activities or investigations were different among the teachers, they commonly incorporated labs or investigations in their science lessons. For this reason, their tendency to use labs was a good starting point for learning to use MIAIM to support student's scientific practices.

Comparison of teachers' instructional practices to MIAIM

In this section, I will report the results from data analysis on class observations and interviews to understand teachers' instructional practices to address scientific practices. In this section, I will compare the teachers' instructional practices to MIAIM. The comparison will be focused on five instructional features of MIAIM: (1) establish a central question, (2) provide experiences with phenomena, (3) make patterns explicit, (4) provide explanations, and (5) apply scientific knowledge to new situations. Figure 4.2 shows frequencies of teachers' use of instructional practice before the intervention.

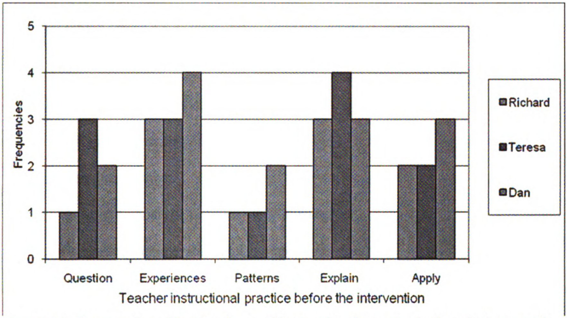

Figure 4.2. Frequencies of teachers' use of instructional practice before the intervention

Establish a central question. The three teachers did not clearly establish central questions for lab activities or investigations that gave a sense of purpose to students' study at the beginning of their lessons. Richard and Dan did not consistently establish central questions of lab activities but, instead, focused on telling procedures or materials. Teresa consistently established central questions, but her questions were sometimes difficult for students to understand.

Richard's instructional practices related to establishing a central question were different among lab activities depending on the purpose. When Richard taught about the sequence of the scientific method, he had students develop their own questions about four different liquids at the beginning of an investigation. However, when he used lab activities to teach about scientific content such as phase change, he did not establish central questions, but told students about procedures or importance of the activities in science. For example, in one lesson, instead of asking a central question, he mentioned what students would to do during a lab activity, like “You will make a temperature and time data table”. Then, he described the procedure of the activity.

> Procedure of the phase change lab:
>
> Mix a little water with the ice.
>
> Turn on the heat.
>
> Gradually heat the mixture while stirring.
>
> Record the temperature at 1 minutes intervals.
>
> Continue to heat the water and record the temperature until the water has been boiling for about five minutes.
>
> Turn the heat off before the water has all boiled.
>
> Graph your data.

The next day, he asked students to measure the temperature again and asked them to graph their data. However, in the lesson, he did not provide a central question but only explained the importance of making a graph (and how to draw it).

In summary, Richard showed inconsistency in establishing central questions. The inconsistencies seemed to result from the two different purposes of using laboratory activities—confirming scientific explanation already introduced and understanding the scientific method.

Teresa consistently asked a central question of each investigation at the beginning of activity. She asked questions like, "How do we know about layers of the earth?" or she read questions written on curriculum materials such as "your job is to change the geologic features of Earth and observe the effects. You will also explore how these features work together to help make a planet habitable to humans." However, the central questions in the two of three investigations were too short or difficult for students to understand. For example, students did not understand a vocabulary word used in her question such as "geologic." In addition, they did not know how they were able to investigate the layers of the earth before she explained that they would use P and S waves to investigate it. In order words, although questions guided the class investigations, the questions were not understandable enough to give students a sense of purpose.

Finally, Dan was inconsistent in establishing a central question for an inquiry activity at the beginning of his lesson. Of his four inquiry lessons, he asked a central question to students twice. For example, he asked "what do you think will happen to water, stones, and sand after 3 weeks of continuous tumbling?" Students made their own hypothesis and compared their hypothesis with results from an experiment. In another lesson, he asked how they knew there was a glacier in Michigan a long time ago.

However, in the other two lessons, he gave names of activities and gave directions of activities without establishing central questions. Worksheets used in the lessons did not also include central questions. For example, the following excerpt shows that Dan only told the name of the activity, materials, and procedures of it without mentioning the purpose or central question of the activity.

Today, we will use sand…We will do something called, sandblasters. Sandblasters is a cool activity. …I'll show you what will go to happen here. I'll demonstrate what you will to do. I'm not say what will happen, you have to observe. I'll show what I expect you to do. Look at me. This is what will happen, we have a box, it has hole in it. It is called sandblaster. This is what will happen, I have some sand right here, and I will pour it here. This will be a file. Don't worry. Sit down. I just put sand right here. OK? And roll it then….

You will have on your own desks, a tray, two cards, one says A and one says B. you will have tapes, you will have one seizure, two Burger King straws…What I am going to do, I'll make something here and you will do an experiment with it. Here's what you are going to do. It says, 'draw a picture of card A after a student has blown through a straw over the sand Gently'. What does that mean? You have a card. It's got either A or B on it. We will start with A.

In summary, Dan also showed inconsistency in addressing a central question of an investigation.

In conclusion, according to MIAIM, the sequence of inquiry activities should start with establishing a central question that gives a sense of purpose to an investigation. In addition, the question should be interesting and relevant for students to be motivated to participate in the inquiry practice. However, the teachers did not consistently or clearly address central questions of lab activities at the beginning of lessons. Instead, they tended to focus on explaining procedures or materials. Although Teresa asked central questions, the questions were sometimes too short or difficult for students to understand. The tendency to not clearly address a central question during classroom activities seemed to be an ineffective practice for two reasons. First, lack of purpose may not be effective to hold student attention long enough to construct scientific explanations from the investigations. It may also lead to students not recognizing the importance of establishing questions in scientific inquiry and connections between questions and experimental design.

Provide experiences with phenomena. The teachers provided experiences with phenomena that were appropriate to help students understand target learning goals. Dan and Richard gave several opportunities for students to interact with materials. Teresa also provided experiences using computer simulations and modeling activities.

Richard provided first hand experiences to teach scientific methods and physical change. These experiences included measuring volume using two different methods, designing and conducting an experiment on density, and collecting data on the change of water temperature. While these experiences were appropriate for target learning goals, he gave only one experiment on each topic and did not relate students' everyday experiences to the topic. For example, in order to help students understand the steps of the scientific method, he had students conduct an experiment while thoroughly following steps he provided. He had students observe interactions of several liquids and make questions about the phenomenon. After making questions, he had groups of students discuss a hypothesis, discuss and choose methods of testing, make a procedure, and a make data table. After checking their procedures with him, students did the experiment following their procedures to find out how each of the color solutions interacted with one another. They wrote their results about the interactions of the four liquids. Through the experiment they found that one solution always layered on top while one always layered on bottom. During class, some of them hypothesized that the solutions probably interacted in that way because of their different densities. They finally measured the densities of the four liquids and proved that the interactions of the four liquids resulted from their different densities. Through this experiment, students had experience of the five steps of the scientific method including asking a question, researching the question, developing hypothesis, experiment, and result and conclusion. This experience was appropriate for learning the scientific method and it was in-depth in that students made their own questions and procedures and figured out the results and made their explanations for the results

In another example, to help students understand phase change of matter, he had students measure ice temperature while boiling the ice. Students put some ice and water in a beaker, heated the water and ice, and recorded the temperature until the water had been boiling for about five minutes. Though the experiment, they had experience with the phase change of water, so that it was appropriate for the learning goal of the lesson. However, students were not requested to do a high level of thinking; instead, they were only asked to observe ice temperature.

In summary, Richard provided appropriate experiences with phenomena with priority to first hand data collection. While he provided an in depth experience to teach scientific methods, he provided only one and shallow experience to teach other science concepts.

Teresa provided experiences with phenomena and prioritized modeling activities. The experiences were one modeling activity on inherited traits, and computer simulations on the structure of the earth and cause and effects of the earth's structure. Although they were not first-hand experiences, they were appropriate for the learning goals. For example, to teach the interior of the earth, for which it is not easy to provide first hand data, she used an internet investigation to show the structure of the earth. After explaining what types of material P and S waives pass through, she showed several models of planets. Students observed the path taken by P and S waves in model planets and sketched the layers on their diagrams and indicated if there were solid or liquid. Through this process, they drew a model of the Earth, which had several layers with solid or liquid. In another example, to teach about inherited traits, she used a modeling activity in where students tracked different traits (represented by colored pom-poms) though three generations.

Teresa's students had fewer opportunities to collect first hand data than Dan's or Richard's class. She was not able to provide first-hand experience probably because of the features of the contents that she taught. However, when there was a chance to use first hand data, she did not. For example, when she taught density, she did not provide any specific objects for students to find out their densities. Instead, she had students practice calculating densities of four liquids of which masses and volumes were given in curriculum materials. This experience is quite different from experiences that Richard's students had when they learned the same topic. Students from Richard's class measured mass and volume of liquids, found out the liquid's densities, and stacked the liquids in pipettes. However, her students calculated densities of four liquids and drew pictures of the sequence of the liquids with different colored pencils without having access to the liquids. In summary, although Teresa provided appropriate experiences with phenomena, she less used first-hand data compared to Richard.

Finally, Dan provided experiences with phenomena for students to understand landforms four times in his classes. He prioritized first hand data collection and observations when providing an opportunity to engage with relevant phenomena. These experiences included changes of stones after three weeks of tumbling, different amounts of sands filed on papers caused by winds, different amounts and speeds of sands in streams of water depending on the angle of the streams, and movement of an ice glacier on sands in an angled big plate. For example, in the tumbler experiment[7], his students had a chance to compare shapes of stones before and after three weeks of tumbling. Their stones became smoother and smaller after rolling with water, sand, and mussel shells. The experience was similar to phenomena that happened on the shoreline in rivers. In another example, he had students observe different amounts of sand filed on two papers caused by winds. This experiment was similar to the phenomena of movement of sands by winds. These examples were appropriate for representing erosive processes. In summary, Dan provided several opportunities for students to observe, and these experiences closely related to real-world phenomena.

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[7] Table 4.3 shows a summary of the experiment.

In conclusion, according to MIAIM, students should have experiences with relevant phenomena with a priority to first-hand data collection. Without the experiences, it is hard for students to understand patterns, rules, models, or explanations related to the phenomena. In addition, constructing knowledge from data is one of the core practices of scientific inquiry. The teachers tended to provide appropriate experiences with relevant phenomena. Dan and Richard focused on first-hand data more than Teresa. Dan's and Richard's students had several opportunities to interact with materials by themselves but Teresa's students participated in modeling activities which provided visual experiences.

Make patterns explicit. The teachers tended not to make patterns in observations explicit. Richard and Teresa gave one experience that was not enough to find patterns or gave scientific explanations including patterns before providing experiences. While Dan provided several experiences with phenomena, he was inconsistent in asking students to analyze data.

Richard did not effectively help students to find patterns by themselves although he tried to provide experiences. He explained patterns of scientific phenomena before providing experiences or he gave only one experience, which was not enough to find patterns. For example, he reviewed an explanation of phase change of matter in class, and his students were able to interpret graphs about phase change and temperature change. After the review, he said that students would "find pattern of phase change regardless of beaker size or amount of ice." Although the results from an experiment might show a pattern on the relationship between phase change and changes of water temperature, he did not give students chances to compare results from each group to find patterns among different experiment settings.

Similarly, Teresa tended not to focus on patterns. She provided explanations and experiences but not had students to attend to patterns in experiences. In addition, she usually gave only one experience with phenomena, which was not enough for students to find patterns.

While Dan focused on providing several experiences related to erosion, he focused less on making patterns in the experiences explicit. During experiments, he asked students to notice the difference of students' observations between two different conditions (two times of seven observations). He asked students to compare results from the activities, although he did not clearly have students find patterns in their results or share their ideas about patterns. For example, he had students write how their stones, shells, and water changed after three weeks of tumbling and why they changed. Through the writing, students participated in an activity of comparing data, which might help students to find out patterns or rules.

In other classes, he did not ask students to analyze data but only to write the data. In addition, he did not ask to students find patterns in several experiences. For example, he had students observe and draw a picture of each 'stream' of water in high and low angles. Although he asked which stream of water was faster, he did not ask students compare the results but only asked students describe what the streams looked like. After the experiment, he had students label their drawings with scientific vocabularies such as source, bank, and channel of a stream rather than help students focusing on the differences of the two streams and the reasons for the difference. In addition, this observation was not connected with other experiences related to erosion or deposits of eroded material. Therefore, although some students may find patterns by themselves through participating in several experiments, neither did he clearly ask students to find out rules or patterns in several observations nor did he have students share their ideas about patterns.

In conclusion, the teachers did not make patterns in experiences explicit. Therefore, students from three classes rarely had chances to participate in a scientific practice of finding out patterns in data. However, it is important to help students to find out patterns themselves as MIAIM and Experience-Pattern-Explanation Framework (Anderson, 2006) insists because scientists make efforts to find patterns or rules beyond their observations.

Provide explanations. The teachers focused more on telling scientific explanations rather than giving students' opportunities to develop their explanations and compare their explanations with scientific ones. I observed only one time in Dan's class that students agreed or disagreed with each other's scientific explanations. Usually, students did not have chance to compare their explanations for observed patterns with scientific explanations introduced, and to revise their ideas when the scientific explanations are plausible and fruitful (Posner et al., 182). Regarding the sequence of providing explanation and experiences, the teachers tended to provide explanations, basic information, or definitions of vocabularies before providing experiences.

Richard provided scientific information through the students' individual book reading or his presentation before providing experiences. Through this sequence, he intended to help students understand the scientific explanation through doing experiments. During pre-interviews, he said, "[the purpose of labs are] Understanding what they read before and interacting with what they read. It's not interacting at the same exact time, but they do get a better understanding of what they should have read". In order words, lab activities were used as a tool to understand or confirm scientific explanations that were presented before.

He used class discussion to explain scientific information. While explaining, he asked closed questions that had correct/incorrect answers such as "What is biology?" or "What is the boiling point of this substance?" He asked a question, students answered, and he evaluated the answer and gave the correct answer if the student's answer was not correct. Although students might be able to develop their own explanations for the patterns in experiments and to compare their explanations with scientific explanations themselves, I heard only scientific explanations discussed in his classroom. In conclusion, students from his class were treated as receivers of scientific information delivered from books and teacher explanations rather than developers of information.

Teresa showed two patterns in providing explanations. First, she sometimes explained scientific information through a presentation before providing experiences.

Differently from Richard's class, she rarely had students read books in her class. Second, after showing simulations, she asked students to describe what they saw in the simulations and provided scientific explanations about the simulations. For example, she showed computer simulations on the cause and effects of geologic features of the earth. After showing the effects of the liquid outer layer of the earth, she asked what happened if the outer layer of the earth was liquid instead of solid. Students described what they saw and she summarized students' description and added what scientists said. Although students might be able to develop their own explanations on the simulations, she usually explained scientific information and students wrote what she said. Similarly to Richard's class, students from Teresa's class did not have much of a role in creating or developing scientific explanations.

Dan helped students to understand scientific explanations three ways. First, he introduced basic information or definitions of vocabularies before providing experiences. For example, he gave an explanation of what sedimentary rocks were and how they were formed before students did an experiment on changes of rocks. He also gave definitions of vocabulary related to 'steam' of water before he had students observe each 'stream' of water in two different angles. During pre-interviews, he also told me that last year he gave basic definitions about electricity for students "to be able to get them to understand that there's a flow that happens." In other words, he tended to give some basic information for students to start their investigations.

Second, he asked some questions for students to develop their explanations for observations (twice). During my observations, he asked students to write answers to questions about "why" something happened in the way that they observed. For example, he had students write their explanations of why they thought that stones, shells, and sand changed. In addition, he asked students to write their answers to the question, "how could sand and wind together make rocks change?" after an experiment with sands and wind. However, in other experiments, he did not ask students to develop explanations. Students only described what they observed during experiments.

Finally, he gave students an opportunity to share their explanations for the reasons that rocks change (one time). He called the activity "science talk" and had students share their ideas and argue with each other. However, in the activity, he did not challenge students to compare their explanations with scientific ones.

In conclusion, Dan's practices for providing explanations had some similarities and differences compared to the goals of MIAIM. Similarly with the intent of MIAIM, he sometimes gave students opportunities to develop their explanations through writing. However, he did not do so frequently. Differently from the intent of MIAIM, he did not give students chances to share their explanations after each experiment. He expressed that although it would be helpful for students to share their findings, he did not have enough time to do so due to teaching several other subjects. He added that sharing was sometimes redundant. Although he had students share their ideas in one class, students only talked about their explanations without specifically referring to evidence from experiments.

Overall, the teachers focused more on telling scientific explanations rather than giving students opportunities to develop explanations and compare explanations with scientific ones. They missed some scientific practices to construct explanations which are important in MIAIM. Therefore, students might not have chances to develop their own explanations because their teachers give the explanations. When teachers provided experiences before explanations, students might have constructed scientific explanations by themselves individually.

Provide opportunities for application. The teachers provided few opportunities for students to apply scientific explanation to new situations. The purpose of application activities was to understand explanations better rather than relating them to student's everyday lives.

When Richard and Teresa, two 8th grade science teachers had students apply scientific knowledge, the application question was not related to students' lives but focused on practicing using knowledge for understanding it better. For example, in Richard's class, he used a lab activity to help students understand the sequence of scientific methods. He described the lab on the curriculum material, "The colored solution lab is an investigation in which you will reinforce the use of the scientific method and gain a better understanding of each of the steps in the method". He also used a lab activity to help students understand phase changes of matter. When explaining graphs related to phase changes of matter, he told, "This graph, many of you have seen this graph before, which we will check ourselves today." Similarly, Teresa asked students calculate densities of four unknown liquids after giving the definition and formula of density.

Dan did not frequently have students apply scientific knowledge to their everyday lives. During my observations, he gave students opportunities to apply scientific ideas to new situations three times. In one case, he showed real-world examples such as rocks or sandpapers at the end of a class but he gave explanations on the examples by himself rather than asking students to apply scientific knowledge. In the other two cases, he used application activities in which students used knowledge of features of the earth to explain pictures of magazines and to tell what features of the earth were on a globe.

In conclusion, application of scientific ideas is a very important practice in science as well as inquiry. However, the three teachers did not frequently provide opportunities for students to apply scientific ideas to new situations. Even when they, did the focus of application was not using knowledge to understand students' everyday lives, but using it to understand the scientific ideas better.

Overall, the teachers used some practices similar to MIAIM but they did not address other important aspect of MIAIM. First, the teachers did not clearly establish central questions for lab activities or investigations that gave a sense of purpose to students' study at the beginning of their lessons. Richard and Dan did not consistently establish central questions of lab activities but, instead, focused on telling procedures or materials Teresa consistently established central questions, but her questions were sometimes too short or difficult for students to understand. Second, the teachers provided experiences with phenomena that were appropriate to help students understand target learning goals. Dan and Richard gave several opportunities for students to interact with materials. Teresa also provided experiences using computer simulations and modeling activities. Third, the teachers tended not to make patterns in observations explicit. While Dan provided several experiences with phenomena, he was inconsistent in asking students to analyze data. Richard and Teresa gave one experience that was not enough to find patterns or gave scientific explanations including patterns before providing experiences. Fourth, the teachers focused more on telling scientific explanations rather than giving students' opportunities to develop their explanations and compare their explanations with scientific ones. Finally, they provided few opportunities for students to apply scientific explanation to new situations. The purpose of application activities was to understand explanations better rather than relating them to student's everyday lives

Comparison of teachers' motivational practices to MIAIM

In this section, I will report the results from data analysis on class observations and interviews to understand teachers' practices to help students value learning science. I will compare the teachers' motivational practices to MIAIM. The comparison will be focused on four motivational features of MIAIM: (1) make the relevance of science to students' lives explicit, (2) catch and hold student's interests, (3) support student's autonomy, and (4) know one's students and use knowledge about the students. Figure 4.3 shows frequencies of teachers' use of motivational practice before the intervention.

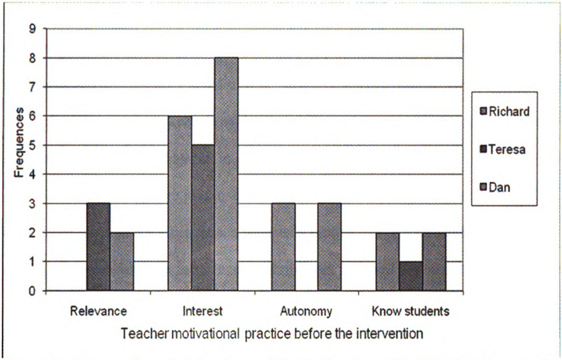

Figure 4.3. Frequencies of teachers' use of motivational practice before the intervention

Make relevance of science to students' lives explicit.

The teachers did not frequently make efforts to make science relevant to students' lives. Richard talked about future jobs or importance of scientific practices from a scientist's perspective as the reason for learning science but did not explicitly relate science to their everyday lives. Teresa and Dan sometimes gave real-world examples in class but their comments on the examples were very short and did not have students talk about the relevance of topics to their lives.

Richard did not make science relevant to the students' everyday lives explicit. During my six observations, he focused on discussing on importance of learning science for future jobs (two times) or tests (once) or from the perspective of science (3 times) instead of relating science to students' lives. Regarding future jobs or tests, he told to students that they should learn science because science was related to many jobs and they

might get those jobs in the future. For example, when he taught branches of science, he asked how many students' parents worked in the area of science. He said that science had many jobs and told his story about why he became a science teacher. He added that although students did not know why they had to learn science now, they had to learn science because they might work in a branch of science someday.

In addition to future jobs as the reason to study science, he explained the importance of some activities from a scientist's perspective. For example, he told students that measurement in science was important "to communicate some data". He also asked students to write down the procedure of their experiments because, "experiments should be duplicated" and "if you don't have procedures written down, other scientists cannot believe you."

In summary, he did not explicitly relate science to students' everyday lives to help them value learning science. Instead, he talked about other reasons for learning science in general or for participating in some activities. However, the reasons—future jobs, tests, or scientific importance— may not be attractive to some students who do not care much about their future jobs or learning in schools.

Teresa tried to relate science to students' lives by giving real-world examples in class. However, she did not frequently do so and even when she did so, her comments were too short for them to understand the relevance of science to their lives. During my six observations, in two classes she gave a real-world example at the beginning of the lesson to establish a central question of the lesson. For example, she told how her husband and her brother in law looked different and gave the question, "how brothers from same parents look different?" She also talked about Italian dressing, in which oil and vinegar were not mixed, and asked students solve problems of density. Although she tried to make the topic relevant to student's everyday lives through her examples, her comments were short (one or two sentences) and she did not ask students to think about similar examples in their lives.

Dan tried to relate science to student's lives by giving real-world examples or relating the topic to Michigan where students lived. During my seven observations, he gave real-world examples one time and related topics to Michigan once. However, he did so in the middle or at the end of activities rather than at the beginning of activities and so, it may not have been easy for students to understand the relevance of the topics to their everyday lives while they were doing activities. In addition, similar to Teresa, he did not have students talk about the relevance of the topics to their lives. Similar to Richard, he gave rationale for doing an activity from a scientist's perspective.

In summary, teachers did not frequently relate science to students' everyday lives. Even when they did, comments on real world examples were short and they tended to give the examples rather than ask students to find the examples.

Catch and hold students' interest. The teachers made some efforts to make science interesting, mostly providing opportunities to engage in hands-on activities or using games, simulations, humor, or other fun features.

Richard tried to catch and hold students' interest by using hands-on activities (three activities) demonstrations (two times) and cartoons (one time) during my observation. First, he used hands-on activities. He had enough materials for each student to find out the interactions and the densities of color solutions for about one week. Even after some students found out densities of the solutions and told them during class, other students still wanted to find out densities by themselves. He gave chances for the other students to find the densities by themselves and was satisfied with his students' engagement in the activities. During class, he asked me, "Did you notice that they don't have to find density but they want to?"

Second, he used demonstrations twice. He put water into a 1000ml beaker and asked one student to put the water from the 1000ml beaker into a cube beaker. The water in 1000 ml the beaker was perfectly put into the cube beaker. He asked, "How many of you are surprised?" and some of his students raised their hands. Even, one of them asked him to do it backward—to put water in the cube beaker back into to the 1000ml beaker. In addition, he showed how a heated Coke can change its shape when he put it in cold water. His students also were surprised at the change of a Coke can's shape. Third, he added some cartoons in his curriculum materials to catch the students' interests. In conclusion, he used hands-on activities, demonstrations, and cartoons to catch the students' interests in class activities.

Teresa tried to catch the students' interests in class activities by using visual models or stories. During my observations, she provided students opportunities to engage in a hands-on modeling activity about generations of traits one time and used computer simulations two times on the structure of the earth and geologic feature of the earth. In addition, she used stories to introduce class activities two times during my observations. The curriculum materials that she used included some stories to introduce activities. She might have been able to make stories realistic and catch students' interests through the stories but she just read the story and asked students to fill out worksheets. One of the stories was the following:

> Congratulations! You just graduated from college and have a job with a doctor as a medical assistant. Your job is to interview patients and identify if the information they give you is about an inherited trait or an acquired trait.

In summary, she used modeling activities and stories to catch students' interest.

Dan tried to catch and hold students interests by using hands-on activities (four activities), games and humor (three times), and authentic materials (once) during my observations. His students engaged in hands-on activities with stones, ice, sands, etc. They played a game with a globe in which students tossed a globe to other students and wherever their left pinky finger lands, they told what landform it was on. Some of activity materials were from students' every day lives such as collecting stones from school grounds, cutting and pasting pictures of magazines. During activities, Dan used humor or other fun features such as "you think that this is a magic. It's not. This is science" or "you will have two Burger King straws [as materials for class activity]. It's important. It should be *Burger King* straws."

His practices appeared to be effective to catch the students' interests in class activities. Students said, "cool" or wanted to look at some materials closely when he introduced some activities or materials. However, when students had to describe and analyze data after doing something with materials, students' attentions or interests in class activities were not held continuously.

In conclusion, the teachers made some efforts to make science interesting, mostly providing opportunities to engage in hands-on activities or using games, simulations, humor or other fun features.

Support autonomy. Richard and Dan sometimes used a few practices to support students' autonomy such as providing choices or solving problems on their own. However, all three teachers used other practices that may not support autonomy such as using extrinsic contingencies or having them follow procedures of activities without providing the rationale for doing them.

Richard used four practices related to supporting students' autonomy. First, he gave students choices on what materials or methods they used, how to design an experiment, and with whom they worked in one experiment. During the experiment, he gave three options to figure out interactions of liquids, using pipette, slinger, and straw. Second, he encouraged students to solve problems in their own ways rather than insisting upon a single method. In the experiment described above, he encouraged students to make their own procedures to find out the interactions of the solutions. Students made their own procedures and he checked the procedure of each group of students. Third, he provided rationales for doing some activities from a scientist's perspective. For example, in the experiment he asked students to write their procedures because experiments should be duplicated or you might have to do it again later. However, he also used other practices that might undermine students' autonomy. He sometimes asked students just to follow directions of experiments without introducing the purposes of the activities.

Teresa did not frequently use practices to support students' autonomy. First, she did not provide choices on students' activities nor did she encourage students to solve problems in their own ways. Students were requested to follow directions of experiments written on worksheets or on the computer screen. Second, she did not provide a meaningful rationale for the class activities or learning science although she sometimes gave short real-world examples. Finally, she used contingencies to motivate students' behavior. When students did not focus on class assignments during experiments, she told them that the assignments would be homework if they did not finish them rather than telling how the assignments would be helpful for them.

Dan used some practices to support his students' autonomy. First, he gave students choices during two experiments such as collecting their own stones or selecting one picture from magazines that they liked. He said that inquiry worked well for students because it gave 'ownership' to students. Because they chose, named, and described the stones, the experiment was theirs. Second, he co-designed one experiment with students without insisting on a single method. Third, he provided rationales for doing some activities from a scientist's perspective. For example, during the experiment with stones, he asked students describe them in order for them to identify their stones with evidence as scientists argue with evidence. He said, "I will pile your stones. You will say that it will be hard to identify my stone. You may think about your stone, but You cannot prove it. Write it [describe the features of their stones]. It is what scientists do. Scientists have evidence. You can use evidence."

However, he also used other practices that might undermine students' autonomy. First, he sometimes asked students to just follow directions of experiments without giving any choices or rationales, or introducing the purposes of the activities. Second, he used contingencies to motivate students' behavior. When students did not focus on class assignments during experiments, he said that the assignments would be homework if they did not finish the work or they would "take a number off". "Taking a number off" was his way of "controlling students' behavior": students had their own cards which were written a number of five to one. 'Five' means good attendance to class activity. When a student did not participate in class activity, and he said to him, "take a number off", the number of him decreased and he had to write the reason why his number was off and had disadvantage in participating in a class auction at the end of a month.

In conclusion, the three teachers used some practices that might support students' autonomy. The practices included providing choices, encouraging students to solve problems in their own ways rather than insisting n a single method. However, they also used other strategies that might not support students' autonomy.

Know one's students and use the knowledge about students. The teachers used some practices to know their student's prior knowledge, interest, and their backgrounds. To understand students' prior knowledge, the teachers did pre-tests on the unit that they would teach or they asked students to make KWL charts. In addition, Richard and Dan asked students to make some products that might introduce themselves. Teresa said several strategies to find out students' interests.

Richard used pre-tests and asked students to make KWL charts to know their prior knowledge. In addition, he asked students to make self-concept. He gave eight categories that students would choose: Family, My favorites, Science class, Hobbies, Chores at Home, Summer, Sports and Food. Among them, family and science should be included and the total would be six categories. In science part, they wrote what they like or dislike. For example, one described that he liked experiments but disliked taking notes and homework. Another described that she liked projects, the teacher and experiments but disliked homework, and huge projects. Richard said that he used the self-concept maps to know his students but did not use it in science class yet.

Dan made a KWL chart at the beginning of a unit to know prior student knowledge. He and his students talked about what they know and what they want to know. He posted the KWL chart on the wall of his class. In addition, he also asked students to introduce themselves on a paper and asked their parents about what subjects their children do well in and what their concerns on their children were. These gave him background information about his students.

Finally, Teresa also did pre-tests to understand her students' prior knowledge. In addition, during pre-interviews, she said that she used several strategies to connect her student's interests such as incorporating drawing or art into science class, making a box that students put notes about their questions, or "In the past I've discovered that they love learning about planets and astronomy so if I can remind them that earth is a planet." I observed two classes where she had her students draw models with various colored pencils. In summary, the teachers made efforts to know student's prior knowledge and backgrounds.

Overall, the teachers used some practices similar to MIAIM but they did not address other important aspect of MIAIM. First, the teachers did not frequently make efforts to make science relevant to students' lives. Richard talked about future jobs or importance of scientific practices from a scientist's perspective as the reason for learning science but did not explicitly relate science to their everyday lives. Teresa and Dan sometimes gave real-world examples in class but their comments on the examples were very short and did not have students talk about the relevance of topics to their lives. Second, the teachers made some efforts to make science interesting, mostly providing opportunities to engage in hands-on activities or using games, simulations, humor, or other fun features. Third, Richard and Dan sometimes used a few practices to support students' autonomy such as providing choices or solving problems on their own. However, three teachers used other practices that may not support autonomy such as using extrinsic contingencies or having them follow procedures of activities without providing the rationale for doing them. Finally, the teachers used some practices to know their student's prior knowledge, interest, and their backgrounds. To understand students' prior knowledge, the teachers did pre-tests on the unit that they would teach or they asked students to make KWL charts. In addition, Richard and Dan asked students to make some products that might introduce themselves. Teresa said several strategies to find out students' interests.

In conclusion, the teachers used some instructional and motivational practices that met the intent of MIAIM but they did not use other practices in the MIAIM. Based on their initial practices and approaches, I provided professional development experiences around MIAIM to the three teachers. In the next section, I will introduce how teacher's approaches and practices changed after the intervention.

Part II: Changes of teaching approaches and practices

My second research question examines what changes in teachers' teaching approaches and practices occur after their participation in the intervention. More specifically, it examines how and what features of MIAIM the teachers used when teaching science. To address this question, I draw on data analysis from classroom observations, interviews, and curriculum materials. After describing changes in the individual teachers' teaching approaches and practices before and after the intervention, I will report patterns in changes in their instructional and motivational practices compared to MIAIM practices

Changes in teaching approaches and practices

Richard's teaching approach and practices

For readers, I will explain what happened during the intervention with Richard. I gave an explanation of MIAIM and showed an example of a lesson plan that fit the intent of MIAIM. I also gave him an idea of helping students to find patterns in elements of the periodic table. Richard made a new lesson plan for atoms and the periodic table. I found out there were few motivational strategies that he planned to use and I encouraged him to use more motivational strategies, such as relate the topic about atoms to students' everyday lives. When he taught acids and bases, I phased out my support.

Analysis of class observations and interviews indicate that there was a small change in Richard's teaching approach after the intervention, but that he used some

MIAIM practices after the intervention. Table 4.4 shows the summary of his teaching approach and practices before and after the intervention.

Table 4.4. Summary of Richard's teaching approach and practices before and after the intervention

		Before the intervention	After the intervention
Unit Topic		Scientific methods & physical change	Chemical change (Atoms, periodic table, acids and bases)
Teaching approach		Didactic + Hands-on approach: Information was presented first and then students participated in hands-on activities to understand sequence of scientific methods and physical change.	Didactic + Hands-on approach: Information was presented first and then students participated in hands-on activities to understand acids and bases. Inquiry approach: Students found patterns in elements by themselves and teacher explained scientific information.
Instructional Practices	Establish central questions	Inconsistently established central questions for hands-on investigations. Told procedures and the importance of hands-on activity from a scientist's perspective	Consistently established a central question for investigations
	Provide experiences with phenomena	Provided hands-on activities that are appropriate for learning goals	Provided hands-on activities that are appropriate for learning goals
	Make patterns explicit	Provided information about patterns before assigning hands-on activities	Had students find pattern in elements in the periodic table by themselves rather than explained the patterns. Had students read information about acid and bases before doing hands-on activities.

Table 4.4.Continued

		Before the intervention	After the intervention
	Provide explanations	Had students read textbooks. Gave a lecture.	Had students read textbooks. Gave a lecture. Had students explain their ideas about patterns
	Applications	Application questions did not relate to real-life situations Had students practice using knowledge to understand it better	Used application activities to help students use knowledge to understand to real-life situation Had students practice using knowledge to understand it better
Motivational practices	Relevance of science to students lives	Not related science to students' everyday lives. Focused on future jobs or from a scientist's perspective	Put efforts to make the relevance of the topics to students' every day lives by doing discussions, giving examples, and having students do research
	Interest	Used hands-on activities, demonstrations and cartoons	Used hands-on activities and demonstrations. Told a story related to the topic that students would learn and allowed them to project themselves into situations
	Support autonomy	Provided choices Encouraged students to solve problems in their own ways	Provided choices Encouraged students to solve problems in their own ways
	Know my students	Assessed their prior knowledge by using KWL and pre-tests Had students to make self-concept maps	Assessed their prior knowledge by using KWL and pre-tests

Teaching approach. Before the intervention Richard used a combination of didactic and hands-on approaches to present scientific ideas. Richard tended to focus on providing scientific explanations rather than helping students construct the knowledge by themselves through participating in scientific practices. Although he used many hands-on activities, he used those activities primarily as motivational and instructional tools to help students understand scientific ideas. After the intervention, he used an inquiry approach to teach the periodic table and a combination of didactic and hands-on approaches to teach other topics.

First, he used an inquiry approach when teaching the periodic table. During the intervention, he told that he had students do a research about features of elements when teaching the topic. I suggested the idea of helping students find patterns in the features of elements that they researched. After the intervention, he designed and enacted lessons that fit the intent of MIAIM. In particular, the sequence of activities fit MIAIM and he put emphasis on helping students find patterns in several elements. Table 4.5 shows the sequence of activities about The Periodic Table Unit from his class. The lesson fit the sequence of MIAIM, which included all steps of the model. He posed a central question about The Periodic Table Unit in the Engage step, he had students research features of elements and present their findings in class. Students had note cards on which they wrote features of each element. In the Explore step, students found patterns for several elements, made their own table of elements, and Richard helped students find patterns. In the Explain step, there were class discussions where students explained patterns that they found and Richard explained how The Periodic Table is organized. Finally, students applied their knowledge about patterns in The Periodic Table to predict some features of elements in the Apply step.

Table. 4.5. Lesson sequence for the periodic table unit from Richard's class

Lesson title	Activity description	MIAIM step
Periodic table	Richard established the central question, "How is the elements of The Periodic table organized?" By using a story, he had his students pretend as scientists who competed with Mendeleev to make a periodic table.	Engage
	Students did research about their own elements and present their findings in class. Students had note cards in which they wrote features of each element. Students found patterns in several elements to make their own table of elements. Richard helped students to find patterns.	Explore
	Students explained patterns that they found and Richard explained how The Periodic Table is organized.	Explain
	Students predicted features of some elements based on their knowledge about patterns in The Periodic Table.	Apply

During the post-interview, he stated that the lessons were helpful for students to understand the patterns in The Periodic Table. While Richard gave students the information about the patterns of elements in The Periodic Table in his previous years of teaching, he tried to help students to find patterns themselves after the intervention. He said, "I think a lot of the students got the idea that it's organized in this way because of this pattern." He also said:

> Most of them had gotten the structure of it pretty well and figured out some of the patterns. There were three to four main patterns they should have found and a couple of them at least had – several of them had at least a couple main patterns – but then there were others that as we were discussing it, you could see them go, "Oh, now it makes sense." So we had a whole class discussion after they individually organized theirs on how it was supposed to be organized and why it was that way. Then I think they wrote down why they organized it the way they

did. When they were organizing, a lot of them were discussing why they were doing it with each other.

In the interview excerpt, he stated that students actively put their efforts forward to figure out patterns in elements and to understand why The Periodic Table is organized in that way. In addition, he said that it was easy for his students to understand chemical bonds because they understood the features of elements through learning about the periodic table. He also stated that he would use these lesson sequences to teach the periodic table in the next year. In this year, because students had difficulties in finding patterns in elements, he would modify the lessons by asking some students to find features of more than one element in order to fill in more blanks for the periodic table.

> Interviewer: So how will you teach periodic table in the next year?
> Richard: I'll probably try to do the same thing, except I think I'm going to fill in more blanks for the periodic table next year. Because I had students research [elements], 24 or 25 of 36 elements were researched [by students]. A couple of students didn't come up with much in some of my classes and so that leaves us with 22, 23 elements out of 36. So there are quite a few holes. And that caused a little confusion. So I think next year, once I assign them – maybe I'll assign some students two or three, the ones that can handle it – and that'll fill in the holes.

However, when he taught about atoms, and acids and bases, he used a combination of didactic and hands-on approaches. Before having students to do experiments, he had students read text books. After reading the books, students did hands-on activities, and he explained scientific ideas. For example, when students learned about acids and bases, students read about what acid and bases are. Then, they did an experiment to figure out whether some liquids are acids or bases. Finally, he and his students talked about the features of acids and bases and results from the experiments.

After the lesson about the acids and bases, I asked him about why he had students read books before doing hands-on activities. He told me that he did this way to give students the purpose of hands-on activities. He said that without reading books, it was hard for students to understand what and why they were doing. It seems that although he posed a central question for hands-on activities, he still thought that students need to have background information to do the activities.

Instructional practices. Richard incorporated some practices of MIAIM in his lessons after the intervention (See table 4.4 for summary). Regarding two practices of providing experiences with phenomena and providing experiences, he did not change efore and after the intervention. However, regarding the other three practices, he showed some changes. First, he consistently included activities establishing a central question for hands-on investigations after the intervention while he did not before the intervention. For example, at the beginning of the unit on the periodic table, he provided a central question, "How is the periodic table of the elements organized?" Similarly, before students participated in lab activities, he stated that students would find out whether some materials were acids or bases.

During the post-interview, he explained the importance of posting a central question for the unit or lessons as an Engage activity. He understood that the steps of the scientific method started with asking a question and that the question helped students focus on what they had to do in class. During the interview, he said:

> For science, the engage part, it really goes along pretty well with the scientific method. And to start off the year using the scientific method, that isn't terrible new for them to see a new question or problem. You're stating the problem. So that went along with pretty much anything we could do in science
>
> ...
>
> that [Asking a central question] really helps them know what they're focusing on. To just say, "Ok, we're focusing on acids and bases today," well, what's that mean, exactly? But when you ask a question, it gets more specific on exactly what you're doing that day.

Second, he had students find patterns in elements in the periodic table by themselves rather than he explained the patterns. However, in other lessons about acids and bases he had students read explanations about acid and bases before doing hands-on activities. In these lessons, although he asked students to find patterns in data about acids and bases during class, they may read information about features of acids and bases through text books.

Finally, he included application activities that helped students use their knowledge into new situations or real-world situations. Although I did not give any specific comments about application, Richard used some application activities that helped students use knowledge to understand real-world situations. For example, he asked students to apply knowledge of neutralization reactions to understand why acid rain affects some locations more than others. However, similar to his instruction before the intervention, some of his application activities focused on helping students understand the learning goals better. During the post-interview, he said that it is hard for them to "apply what they've learned in the whole unit to other things around them. They're able to do it, it's just a more challenging part."

Motivational practices. Richard used some motivational practices listed in the MIAIM. As he did before the intervention, he used hands-on activities, demonstrations, and games to catch students' interests, and talked about the importance of learning science for good grades in high school. However in addition to these practices, he used other practices after the intervention. First, he gave more effort to make the relevance of science to students' lives explicit. During the intervention, I suggested him to think about how to relate the lessons to students' everyday lives because his lesson plans did not include any activities relating science to student's lives. The lesson plans included using only games or extrinsic rewards such as receiving a Jolly Rancher candy. However, he revised his lesson plans and included several activities to make the relevance of science to student's lives explicit including a whole class discussion on atoms' use in our lives and individual research about elements used in home products. He also showed real-world examples of elements used in daily products such as Ammonium Lauryl Sulfate, which makes shampoo sudsy. After the instruction, he said that his students had a better understanding of how important an atom is. He also expressed that the home product research would be "an eye-opener" for them to learn about atoms. He said,

> When we got talking about atoms, we watched the Bill Nye and we talked about how atoms are in everything. A lot of kids seemed to think, "Wow, it's in everything." I think they got a better understanding of how important it is because of our discussion of how much we rely on products that are made from elements that we need to understand how the atoms and those element s combine to get the product. I don't think they fully understood, but maybe they will. It was a pretty good conversation yesterday about how much we use chemistry in our everyday lives and we don't even realize it. So it was a good discussion yesterday

Later, when he taught acids and bases, he also related the topics to students' lives. In class, he talked about why measuring pH and knowing the appropriate pH in water tanks and swimming pools would be helpful to our lives. He also talked about the effects of acid rain in our lives.

In addition, he used a story to make a context in which students had to make their own periodic table (See table 4.6). He had his students pretend that they would be the people creating a periodic table in the late 1860s when Mendeleev tried to create his periodic table. Richard used the story in order to introduce an element research project in which each student should find information about features of one element such as atomic number and mass, and to establish a central question about The Periodic Table.

Table 4.6. Story used in element research project from Richard's class

Imagine that you are a scientist during the late 1860's. And imagine that you are on a team of scientists (the rest of the class) researching substances that you call elements. You are researching these elements because you and your team want to be the first to make an easy to understand organizational chart of all known elements. At the same time Dmitri Mendeleev, a Russian scientist, is also hard at work organizing the elements. Do you want him to be the first…NO… You, and each member of your team, are in charge of finding information about different elements that you can report back to the team. You will then take this information that you find and try to organize all of the elements (1-36) and become the first people to make a table of the elements that will be use by people around the world making important advancements in chemistry.

In summary, during intervention, I encouraged Richard to help students to find patterns in elements in the periodic table and use more motivational strategies. After the intervention, Richard incorporated some features of MIAIM. He taught the periodic table with an inquiry approach and had students find patterns in data. The sequence of activities about the periodic table met all steps of MIAIM. When teaching other topics, he used a combination of didactic and hands-on approaches but he constantly established a central question for hands-on investigations, and applied scientific explanations to new situations. Regarding motivation he designed and enacted several activities relate science to students' everyday lives. In addition, he used a story to make a context in which students had to make their own periodic table.

Teresa's teaching approach and practices

For readers, I will explain what happened during the intervention with Teresa. I gave an explanation of MIAIM and showed an example of a lesson plan that fit the intent of MIAIM. But, she did not give written lesson plans to me and did not talk about her lesson plans in detail. Instead, one week or two days before her teaching, she briefly told the topics of her lessons and what methods she would use such as internet investigation, or modeling activities. Before her fist inquiry lesson, I asked her to follow the step of MIAIM. After that I did not ask again. In the other lessons, I asked her to use more motivational strategies.

Analysis of class observations and interviews indicate that her general teaching approach was similar before and after the intervention but that she used a few MIAIM practices after the intervention. Table 4.7 shows the summary of her teaching approach and practices before and after the intervention.

Table 4.7. Summary of Teresa' teaching approach and practices before and after the intervention

		Before the intervention	After the intervention
Unit Topic		Genetics & Structure of the earth	Plate tectonics, earthquakes, volcanoes
Teaching approach		Didactic approach: Information about definitions and formula were presented without hands-on experiments Inquiry approach: Students were given data to understand scientific explanations.	Didactic approach: Teresa explained information about plate tectonics.. Inquiry approach: Students found patterns in data about earthquakes and volcanoes and then, Teresa explained scientific ideas.
Instructional practices	Establish central questions	Consistently established central questions for investigations.	Consistently established a central question for investigations.
	Provide experiences with phenomena	Provided a few experiences with phenomena that are appropriate for learning goals Used modeling activities rather than first-hand data collection	Provided a few experiences with phenomena that are appropriate for learning goals Used second-hand data and computer simulations rather than first-hand data collections
	Make patterns explicit	Explained information about patterns rather than had students find patterns themselves Provided one experience with phenomena that was not enough to find patterns in data	Gave students opportunities to find patterns in data
	Provide explanations	Gave explanations without lab activities Did not give students many chances to create explanations after seeing simulations	Give students opportunities to develop their ideas about explanations of patterns.
	Applications	Gave a few real world examples Had students use knowledge to practice formulas or scientific terms	Increasingly used application activities related to real-world situations

Table. 4.7. Continued

		Before the intervention	After the intervention
Motivational practices	Relevance of science to students lives	Gave a few real world examples Not give other reasons for learning science. Did not ask students to talk about the relevance of topics to their lives	Asked students to talk about the importance of topics to them.
	Interest	Using visual models and stories. Used drawing in science class	Use visual models & hands-on activity.
	Support autonomy	Not provided choices on students' activities Not encouraged students to solve problems in their own ways.	Provided choices on students' activities Encouraged students to solve problems in their own ways. Used contingencies to motivate students.
	Know my students and use knowledge about my students	Assessed student's prior knowledge by using pre-tests Used several strategies to connect her student's interests such as incorporating drawing or art into science class.	Assessed student's prior knowledge by using pre-tests. Had students do a hands-on activity about volcanoes because her students wanted to do.

Teaching approach. Teresa's general teaching approach was similar before and after the intervention. As she did before the intervention, she sometimes used a didactic approach after the intervention. She presented scientific information without giving students opportunities to do experiments and had students practice using the knowledge to get good grades. For example, when she taught the three types of boundaries of plate tectonics, she drew the structures of the boundaries and explained definitions, examples, and effects of the boundaries. Students took notes on what she explained and drew the structures. After the class, she told me that she wanted to provide as much as information possible at the beginning of the unit of plate tectonics because she wanted her students to do their projects, in which students had to show what they understood about plate tectonics to get good grades. The projects that students had to do included activities such as coloring each plate tectonic or labeling each plate with the correct name.

During the post-interview she stated that an inquiry approach was good to develop student's high-level thinking skills, but she pointed out that it was hard to develop "an investigation around a subject you're [students are] not that familiar with." She also mentioned that whether she could do an inquiry-based lesson was not only related to her educational theory but also related to other "practical situations" such as her schedule or availability of necessary materials. For example, because she was the director of the science department of the school and she sometimes did not teach science due to doing other work, she had to design class activities to meet her schedule, which influenced the sequence of activities in class, and sometimes gave explanations first before assigning experiments.

However, in other classes, she used an inquiry approach as she did before the intervention. Although she used the same approach before and after the intervention, after the intervention she used some MIAIM practices more than she did before. After the intervention, she taught three inquiry lessons about earthquakes and volcanoes. Table 4.8 shows the summary of the lessons and how they fit the sequence of MIAIM. In the Engage step, she posed a central question for the following inquiry activity and students made predictions based on questions. In the Explore step, she provided real-world data, requested students to find patterns in data, and asked some questions to help students develop their explanations. In the Explain step, she gave explanations about the patterns during the class or she corrected students' misconceptions after she assessed students' understandings of scientific explanations. Finally, in the Apply step, one lesson included an application activity, which asked students to use scientific knowledge to a new situation.

Table 4.8. Sequence of activities on three separate lessons from Teresa's class

Lesson	Activity description	MIAIM steps
Where on earth?	The teacher established a central question, "Where do you think most earthquakes and volcanoes in the world occur?" Students made predictions.	Engage
	Students mapped out some of the recent volcanoes and earthquakes activities that have occurred across the world. They compare their maps with another map that shows plate tectonics, and found patterns between the maps.	Explore
	Students shared their ideas about the patterns and the teacher explained the patterns.	Explain
Some Go "Pop," some do not	The teacher introduced an activity and asked students to find patterns in maps about volcanoes.	Engage
	Students located three types of volcanoes on a map and analyzed the locations of different types of volcanoes. They had chances to develop their explanations about relationships between the locations of different types of volcanoes and the composition of the crust under the continents where volcanic activities occurred.	Explore & Explain
How are earthquakes related to plate tectonics?	The teacher asked students to predict where most earthquakes would occur.	Engage
	The teacher showed computer simulations about locations of earthquakes and students found patterns of earthquake locations compared to the locations of plate boundaries.	Explore
	Students wrote explanations about types of plate tectonics and earthquakes.	Explain
	Students predicted which cities are likely to be affected by earthquake activity	Apply

For example, in a lesson about plate tectonics and earthquakes, in the Engage step, she asked students at the beginning of the lesson to predict where most earthquakes would occur. Then, in the Explore step, she showed computer simulations about locations of earthquake and students found patterns of earthquake location compared to the location of plate boundaries. In the Explain step, Students wrote their explanations about types of plate boundaries and earthquakes. At the end of the lesson, in the Apply step, students applied their knowledge about earthquakes and plate tectonics to predict which cities were likely to be affected by earthquake activity. In this lesson, activities were sequenced in the order of Engage-Explore-Explain-Apply steps.

Based on her sayings during post-interview, MIAIM seemed to be a role to her to support her existing teaching approach. During the post-interview, she said, "It's [MIAIM is] really similar to the model that I use." However, she also stated that MIAIM helped her make sure whether she presented activities in a way that is similar to inquiry-based lessons. In particular, she said that it was helpful for her to think about setting up problems or situations at the beginning of lessons. The following is the interview excerpt.

> It made me more accountable to making sure that – with inquiry it's not only about what you're presenting. I could do the same assignment and present it in different ways, but I have to make sure I'm approaching it with the students from the angle of inquiry so that when I'm doing this it keeps me more aware of why I chose the assignments I chose and how I need to introduce them to make them most effective. Because anybody could come in and go to my files and photocopy stuff, but they're not going to present it in the same way. You can even take

> inquiry lessons and not introduce them in the right fashion so they end up not being an inquiry lesson. It just made me more aware.
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> ...
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> Particularly the beginning – setting up the problem. Setting up the situation. Getting them to look beyond find an answer to thinking about how – being able to explain their choices...Trying to get them to that sort of thinking and not just looking for the answer to get done. A lot of that comes with the setting up.

Instructional practices. She showed a small change in her use of MIAIM instructional practices after the intervention (See table 4.7 for summary). Regarding three practices of posing a central question for investigation, providing experiences with phenomena and providing explanation, she did not show big differences before and after the intervention. However, she put efforts to helped student to find patterns in data and used application activities after the intervention more than she did before the intervention. First, after the intervention, she gave students chances to find patterns in data about earthquakes and volcanoes and develop their explanations about the patterns while she did not before the intervention. Before the intervention, in her inquiry lessons, she put her focus on helping students understand scientific explanations or models rather than helping students find patterns in data. When I asked her to make patterns in data explicit through class discussion, she had students to find patterns and share their ideas of patterns. When I phased out my support, she continued to have students to find patterns in data but did not ask students share their ideas of patterns.

Teresa also increasingly used application activities related to real-world situations after the intervention. In addition to adding application activities at the end of classes, she had three application-based lessons, where students used their knowledge about earthquakes and volcanoes to understand real-world situations or do an experiment about volcanoes. Two of the three application lessons focused on applying scientific knowledge to real-world situations. For example, in one lesson, students conducted research about the effects of volcanoes on the communities near the volcanoes. Although some students expressed that it was hard for them to find information about specific volcanoes though the Internet, students had an opportunity to read other people's experiences relating to volcanoes and about what positive and negative effects volcanoes had on the people's lives.

Motivational practices. She did not show a big difference in her use of MIAIM motivational practices before and after the intervention (See table 4.7 for summary). However, she made more efforts to make science relevant to students' lives explicitly after the intervention compared to before the intervention. In particular, she had three discussions on why it is important to learn about some science topics. Although earthquakes and volcanoes are phenomena that students have heard about, and that they have had great influence on human lives, they did not state during class discussions that learning about these topics was important to their lives. Part of the reason seemed to be the fact that there are seldom earthquakes or no volcanoes in Michigan and, therefore, Michigan is seen as a safe place to live. They said that they had to learn these topics "for high school", "[for a] test", or because "teacher [she] should teach it" rather than because these topics relate to their lives. Teresa finished the discussion with short comments such as "you don't want to decide to live close to volcanoes."

During the post-interview, she reflected on her using of the motivational practices and said that students are too immature to understand why learning specific topics are important. The following is her interview excerpt.

> Because I don't t think they do, but it's a level of maturity. If I tell them, in fact I do tell them, it's good for them to practice this sort of thinking skills because they're applicable when you go to math, when you go to college. That's too far ahead; they're just looking towards tomorrow. ...So I think it's important that we understand the value, but I'm not sure that they will.
> ...Grades [are important to students]– [students think]'I need good grades for college, for scholarships, I need to pass so I can be on sports teams.' Sports teams are the big motivation. But for individual topics, they couldn't necessarily tell you why it's important to have math or even reading. I think that comes back to maturity levels.

In the interview, she expressed that although the valuing of learning science is important, it is not easy for students to understand why individual topics in science are important to them because of their level of maturity.

In conclusion, during intervention with Teresa, I explained MIAIM and before her teaching, I sometimes asked to use some practices of MIAIM. After the intervention, Teresa's teaching approach did not change substantially. She used a didactic approach to teach plate tectonics. In other classes, she used an inquiry approach and her lessons fit all steps of MIAIM. She consistently posted central questions for investigations, asked students to find patterns in data, and used many application activities. She also made more efforts to make science relevant to students' lives explicitly after the intervention.

Dan's teaching approach and practices

For readers, I will explain what happened during the intervention with Dan. I gave an explanation of MIAIM and showed an example of a lesson plan that fit the intent of MIAIM. Dan talked about how he had taught an electricity unit for previous years and showed worksheets that he had used. I suggested that he include a central questions for investigations and questions about finding patterns in data on his worksheets. I also asked him to use more motivational strategies such as relate science to their everyday lives and use stories to catch students' interest in hands-on investigation.

Analysis of class observations and interviews indicate that Dan's teaching approach was similar before and after the intervention but that he incorporated many aspects of MIAIM after the intervention. Table 4.9 shows the summary of his teaching approach and practices before and after the intervention.

Table 4.9. Summary of Dan's teaching approach and practices before and after the intervention

		Before the intervention	After the intervention
Unit topic		Land forms	Electricity
Teaching approach		Inquiry approach: Dan had students collect and analyze data related to land forms.	Inquiry approach: Dan had students figure out how electricity work.
Instructional Practices	Establish central questions	Inconsistently established central questions for investigations. Told procedures, materials, and names of the activity instead of establishing central questions of the activities	Consistently established central questions for investigations
	Provide experiences with phenomena	Provided experiences with phenomena with priority of first hand data collection and observation	Provided experiences with phenomena with priority of first hand data collection and experiment
	Make patterns explicit	Did not make patterns in the experiences explicit.	Focused on help students find patterns in data
	Provide explanations	Provided basic information. Gave students opportunities to develop their explanations for observed patterns. Had students share their explanations	Provided basic information. Gave students opportunities to develop their explanations for observed patterns. Had students share their explanations
	Applications	Gave a few real world examples. Not asked students to apply scientific knowledge to real world situations	Gave opportunities for students to apply knowledge to real world situations

Table. 4.9. Continued

		Before the intervention	After the intervention
Motivational practices	Relevance of science to students lives	Give a few real world examples. Did not ask students to talk about the relevance of topics to their lives	Gave real world examples Had students write essay about their experiences related to a blackout Asked students to talk about the relevance of topics to their lives
	Interest	Used hands-on activities, games, humor, and authentic materials.	Used hands-on activities, games, humor. Told a story related to the topic that students would learn and allowed them to project themselves into situations
	Support autonomy	Gave students choices Encouraged students to solve problems in their own ways.	Have students solve problems in their own ways Encouraged students to solve problems in their own ways.
	Know my students	Assessed their prior knowledge by using KWL. Had students introduce themselves and asked students' parents about their child	Assessed their prior knowledge by using KWL.

Teaching approach and instructional practices. Dan used an inquiry approach for teaching science before and after the intervention. However, after the intervention, he used many aspects of MIAIM in his inquiry lessons, expressed the importance of finding patterns in data in science class and expanded his goals in teaching science.

First, I will explain how his lessons fit the intent of MIAIM. I observed his seven classes after the intervention. Of seven classes, there were four inquiry lessons whose sequences of activities of the lessons fit the steps of MIAIM quite well. Table 4.10 shows the description of each lesson and how the activities in the class met the sequence of

MIAIM. In the Engage step, the lessons included activities of posing a central question and giving students chances to make predictions in response to the questions in the beginning of lessons. In the Explore and Explain step, the lessons also included activities for students to collect and analyze data, find patterns in data, and develop their ideas about patterns and explanations in the middle of the lessons. His students participated in experiments before he gave scientific explanations. Finally, in the Apply step, one class included an application activity at the end of class.

Table 4.10. Sequence of activities on four separate lessons from Dan's class

Lesson title	Activity description	MIAIM step
Static Electricity	Students made predictions of what might happen when some materials are close to each other	Engage
	Students had experiments with wood, balloon, thread, and so on. Students found patterns in the data and developed their explanation.	Explore and Explain
Light it up!	The teacher asked a central question and students made predictions on whether they could make a bulb light up with some materials.	Engage
	Students made their design to make bulbs light and test their predictions. They found patterns in the data.	Explore
	The teacher explained circuits	Explain
Motors	The teacher asked a central question, "how do motors work?"	Engage
	Students connected several ways to make motors work and draw their results. They developed their explanations about the results	Explore and Explain
Conductor and insulator	Students made predictions about whether some materials listed in worksheets such as chalk, nail, penny, and rubber band were conductors or insulators	Engage
	They observed whether they were open or closed circuits. They found patterns in data and wrote their explanations about the results.	Explore & Explain
	The teacher asked an application question and students wrote their answers.	Apply

For example, in a lesson about making a bulb light, whose title is 'light it up!' in table 4.10, at the beginning of the lesson, Dan established a central question, "how does electricity work?" He stated, "We will do something to try to figure out how electricity work. Remember what you did. You had your ship wrecked. You tried to make a bulb work... You had great ideas. We will investigate that. You can pretend that you are on the shipwrecked island. We will give you some materials for you to try to make a bulb work." Students made predictions on whether they could make a bulb light up with some materials. This is an Engage step. Second, in an Explore step, students tried to make bulbs lights in the three experimental conditions—one bulb and one battery; one bulb, one battery, and one wire; and one bulb, one battery and two wires. They wrote their results and he asked students to write their answers on the following two questions: "What patterns do you notice? What do you notice MUST happen in order for the bulb to light?" Finally, in an Explain step, Dan explained circuits and showed other bulbs to explain the flow of electricity in bulbs. This is an Explain step. In summary, this lesson included Engage-Explore-Explain steps of MIAIM.

These lessons sequences of his four inquiry lessons differed from those of his last year's inquiry lessons. Based on the evidence from his last year's worksheets used in his class, and interviews with him, this year Dan put more efforts into establishing central questions for hands-on activities, added an activity for students to find patterns in data, and focused more on doing application activities compared to his previous teaching on the same topic.

In addition, the worksheets used in the four inquiry lessons perfectly matched the sequence of activities in the classes. It included title, a central question, and places for students to write their hypothesis, results, and conclusions. While his previous year's worksheets included only materials, procedures, and some results, this year's worksheets included a big question, questions about patterns or applications. Regarding the new format of the worksheet, he explained that it is more scientific and he would use this format in the next year when teaching electricity He said,

> They [worksheets] are going to stay like this because this is a great way to engage them. And the data, basically it's following the – this would be your introduction and this would be your materials and your data. And your results are right here and your conclusions. So it basically is following a science format that I really believe in. You should know!

In the other three of seven lessons, at first he assessed students' prior knowledge at the beginning of the unit. It was necessary for him to know what students knew and what they wanted to know. In another lesson, he had students play a game with electricity as an application activity after students participated in some inquiry lessons. Finally, at the end of the unit, he had students argue with each other about their explanation of how electricity works. It would qualify as an Explain step of MIAIM.

In addition to using several aspects of MIAIM, he seemed to have a more sophisticated understanding about scientific inquiry. During the post-interview he expressed the importance of finding patterns in data in the inquiry process. He regarded it as important in science because it can "make a stronger argument," "make a conclusion or correlation better," and "apply better," and it is a "repetitive nature of experimentation." He also added that he would continue to help students to find patterns in data. The following excerpt shows how important he thought finding patterns in data in science class was.

> Dan: I have included in there a piece about patterns and I will continue to use that because I think it's a very important piece for them to look at. Always looking for patterns that they're seeing. I hadn't ever looked at it that way in the past, but I think it's a very important piece to look at.
>
> Interviewer: Why do you think it's important to look at?
>
> Dan: That's one way that you can tease out differences in your data. To be able to look at things and be able to identify – this is a pattern and this is a different pattern and this is another pattern. Look at all those and which one of these is going to be important? I just want them to look at the patterns. It is also tying in with math and you can tie it in with social studies and you can tie it in with literacy. No reason not to tie it in here and he's very specific about it. Because truly, in science, you look for patterns. And repetitive nature of experimentation, it has to be replicable. So you have to look for a pattern that happens and that's an extremely important piece for science. So I did want to include that and I will continue to include that in whatever I'm looking at.

In addition, during the post-interview, Dan clearly expressed his desire to help students to apply scientific knowledge to their lives. According to his pre-interview data, his goals had been helping students understand scientific explanations and experience scientific knowledge through participating in hands-on activities or field trips. During the post-interview, he still expressed that these goals were important. However, he added one more goal, helping students to use the knowledge in their everyday lives. He said, "I really want the kids to be able to apply the science that they're learning to their everyday life – to make it applicable. So that they can understand it and be able to use it."

> I: You say your goal is to apply science to their lives. What do you mean by 'use the science' that they learned in their everyday life?
>
> Dan: If they learn something about electricity, say, that they can go out and they can see that this is what they're learning about and this is why, say, a switch works, or why if a certain area of the house is dark, they know there's a broken circuit...
>
> Just for them to be able to look at the world in a new way and understand that there's more to the world than just that it's been there....Things they're learning about can help them understand how things work.... Make connection with their everyday life. What they're learning in class, they can connect it and therefore make it important"

In interview, he was very specific that he wanted his students to use their knowledge to see the world in a new way and that the application of scientific knowledge makes the learning of science important. Finally, to accomplish his goal, he said, "I'm going to be more specific in asking for application to their own lives. I've done that in the past, but I'm going to be probably a little bit more noticeable in asking questions like that."

Motivational practices. Regarding motivation, he put more effort to relate science to students' everyday lives and modified class activities to catch students' interest when addressing MIAIM. For example, before doing any inquiry lessons, he designed two activities to make science relevant and interesting to the students. In the first activity, he displayed several pictures which showed peoples' lives without electricity a long time ago. Then, he showed a PowerPoint presentation about electricity usage all over the world and a picture about a blackout in the eastern part of the USA. Finally, he asked students to remember a time they were in a blackout and what they couldn't do because of there was no electricity. He asked students to write about their experiences during the blackout. He asked questions, "What did you do differently? What couldn't you do anymore? [and] How did you have to change?" While he showed the blackout picture in his previous years' teaching, he added the questions to relate electricity to students lives in this year's teaching. The purpose of showing the pictures and remembering their experiences in a blackout was for students to understand the need for electricity in their lives.

Next, he introduced a story about being 'shipwrecked without electricity' to make the need for learning about electricity realistic (see Table 4.11. for the story). The story created a situation in which students had to make an electric light to send an SOS signal to the other ship to save them. The story said that their class left for Viet Nam by ship to find treasure but along the way, they ran into a huge storm that caused all their electric motors to break, and their ship was marooned on a small island. On the island, there were no people, there were no houses, and there was no electricity. They were hungry the next day but there was no electricity to cook any food. That night, they saw a ship passing the island and wanted to contact it. They had no radio and no lights from the ship because there was no electricity. Fortunately, from their ship they found some materials that might be used to light a bulb and decided to make an electric light to send an SOS. After telling the story, he asked students to write their answers to questions, "How can we make the bulb light? What materials are appropriate for making the bulb light?" Then, students had an investigation about it. Although he used the story because of my suggestion, during the post-interview, he stated three benefits of using the story: it was engaging; and it provided students with a reading and writing format; and it could be used as a pre-assessment (assessing students' ideas about how to make bulbs light up and what materials are needed).

Table 4.11. Story of shipwreck without electricity from Dan's class

Our class left for Viet Nam by ship to find treasure but along the way, we ran into a huge storm that caused all our electric motors on our ship to beak. As a result, our ship was marooned on a small island. We were lucky because we were alive in spite of the big storm. We searched for people in the island. But, there was no people, no houses, and no electricity. He had to survive there. At night, it was very dark and cold. There were sounds of wild animals. We were afraid, and tired. We slept in a large, damp and dark cave. The next morning, we searched for ways to escape from the island. But there seemed no way off. In addition, we were hungry. However, there was no electricity on the island to cook any food. We ate crackers and drank water. That was it. That night, fortunately we saw a ship passing the island. We were excited and wanted to contact it somehow. We had not radio or lights from the ship because there was no electricity. Fortunately, from our ship, we found some materials that might be used to light a bulb. So we decided to make an electric light to send an SOS, a signal to the other ship to save us.

In the middle of the unit, he used similar practices to motivate students to learn science as he did before the intervention. The practices included using hands-on activities, games and humor. Finally, at the end of the unit, he discussed the relevance of the topic to students' lives to help them understand the importance of learning about electricity. He asked the question, "Is electricity important to know about?" and the students had a discussion. His use of motivational practices met the intent of MIAIM. As MIAIM describes, he helped students understand the relevance of the topic to students' lives and caught students' interest. He also used hands-on activities to catch and hold students' interest in the inquiry lessons. Finally, as MIAIM places emphasis on understanding the role of science at the Apply step or at the end of lessons or units, he asked students to discuss on the importance of learning electricity.

In conclusion, during intervention with Dan, I explained MIAIM, commented on his worksheets used in previous years, and asked to use more motivational practices. After the intervention, Dan used an inquiry approach for teaching science and used many aspects of MIAIM in his inquiry lessons. He consistently established central question for investigations, helped students find patterns in data, and asked students to apply scientific ideas to new situations. In addition to doing these practices, he talked about the importance of finding patterns in science and helping students apply scientific ideas to their lives. He also revised his worksheets used in his lessons. Regarding motivational practices, he used practices to relate science to students' lives. He also used a story to make a context for hands-on investigations and after using the story, he elaborated the benefits of using the story to student's learning and motivation.

Changes in teaching practices compared to MIAIM

Patterns in changes of teaching practices

In this section, I will report patterns in changes in the teachers' instructional and motivational practices after they participated in the intervention. In analyzing data related to teaching practices, I found evidence that teachers used several practices similar to features of MIAIM when they taught science after the intervention. Figures 4.4, 4.5, and 4.6 show the frequencies of using practices that met the intention of MIAIM. Patterns across teachers indicate an increase in focus after the intervention on four practices. They are establishing a central question, finding patterns explicit, providing opportunities for applications, and making the relevance of the topic to students' lives explicit. Finally, although there was no increase in frequencies of using practices to catch and hold students' interests, two of the teachers used different kinds of practices to make science interesting to students after the intervention. In the following paragraphs, I will explain how teachers used these practices and then describe the other practices that did not increase or change.

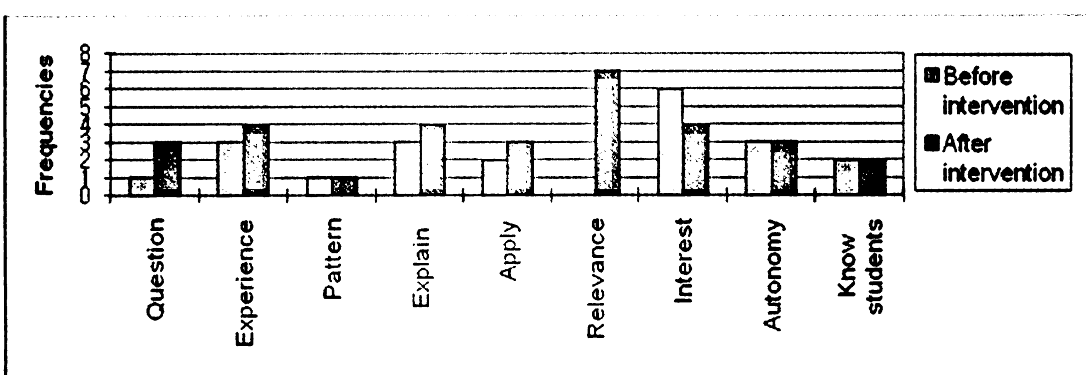

Figure 4.4. Frequencies of using MIAIM practices from Richard's class

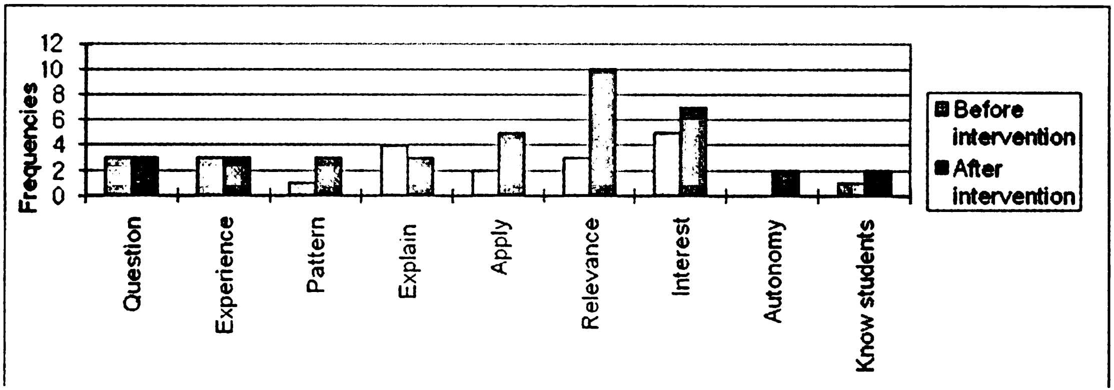

Figure 4.5. Frequencies of using MIAIM practices from Teresa's class

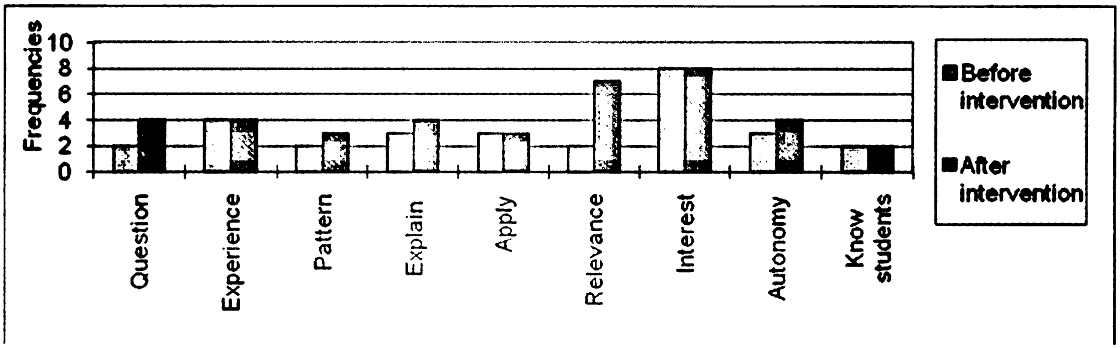

Figure 4.6. Frequencies of using MIAIM practices from Dan's class

Establish a central question

The three teachers posed central questions for hands-on investigations that gave the purpose of the investigations to students at the beginning of class activities. In particular, Richard and Dan more clearly and more consistently established a central question after the intervention. Teresa consistently posed central questions for investigation before and after the intervention.

Richard attended to central questions for investigations in class after the intervention more than he did before the intervention. Before the intervention, he established a central question in one of three lab activities although during pre-interviews, he stated, "Usually we start out with a scientific method, asking a question…some kind of problem they're figuring out." Without establishing the central questions, he sometimes explained only procedures or the importance of the experiment when students did not engage in the experiments. However, after the interventions, he spent his efforts to establish central questions for investigations about the periodic table, and acids and bases. to motivate students to do projects on atoms and on The Periodic Table. For example, in his lesson plan, he wrote a central question for a Periodic Table inquiry lesson, "How is the periodic table of the elements organized?" In order to make the question understandable and interesting, he said, "You are researching these elements because you and your team want to be the first to make an easy to understand organizational chart of all known elements...you find and try to organize all of the elements (1-36) and become the first people to make a table of the elements that will be use by people around the world making important advancements in chemistry."

Dan consistently established a central question for investigation in class after the intervention. Before the intervention, he sometimes focused on explaining materials and procedures instead of posing central questions (2 of 4 investigations). Even when he asked a central question, he did during the activity rather than at the beginning of the activity (1 of 4 investigations). His curriculum materials that were distributed to students also did not include the central questions. However, after the intervention, he clearly asked a central question for investigation at the beginning of the lesson (4 of 4 investigations) and gave students chances to make predictions in response to the questions. For example, in a class about making a bulb light, he said, "We will do something to try to figure out how electricity work. Remember what you did. You had your ship wrecked. You tried to make a bulb work... You had great ideas. We will investigate that. You can pretend that you are on the shipwrecked island. We will give you some materials for you to try to make a bulb work."

In addition, different from the worksheets on the electricity unit used in his class in previous years, the revised worksheets after the intervention had central questions at the top of them. In his four inquiry activities, 4 of 4 worksheets included central questions, while none of them included central questions in the previous years' worksheets. For example, in the investigation of how to makes a motor work, he included on a worksheet the question, "How can you get a motor spin using a battery, motor, and wires". In addition, he added the question, "Can electricity travel through all materials?" on a worksheet about conductors and insulators. Regarding the change of including a central question for investigation on worksheet, he expressed during the post-interview that posing a central question is a great way to engage students and it is introduction of the lessons. In summary, Dan consistently established a central question for investigation after the intervention and had an understanding of the need for posing a central question at the beginning of an inquiry lesson.

Overall, after the intervention, two teachers showed increased efforts in establishing a central question for an investigation. They more consistently and clearly addressed central questions at the beginning of activities.

Make patterns explicit

The three teachers focused on helping students finding patterns in data by themselves after the intervention more than they did before the intervention. Richard and

Dan, especially, increasingly spent their effort to help students find patterns during class. They also reported during post-interviews that helping students find patterns was useful for students' understanding or that finding patterns is one of the important scientific practices.

Richard spent time on helping students find patterns in data or information by themselves after the intervention more than he did so before the intervention. Before the intervention, he used the term, 'pattern', in class but he did not effectively help students to find patterns by themselves because he gave explanations including patterns before having them conduct experiments. After the intervention, Richard helped students find patterns by themselves when he taught The Periodic Table. Especially when he taught The Periodic Table, he spent several days for students to find patterns. He gave students chances to find patterns among 24 elements and construct a periodic table by themselves. Because students had difficulties in finding patterns among different elements based on some information on each element's properties, he had to do a lot of coaching. However, many students finally understood patterns among elements and why the periodic table was organized in that way.

Helping students to find patterns in several elements by themselves was a new teaching approach for him. He told me that he directly gave information on the patterns of elements in the periodic table in the last year. During the post-interview, he reported that this new teaching approach was useful to help students understand the periodic table.

> I think a lot of the students got the idea that it's organized in this way because of this pattern. Originally, it was atomic mass, now we do it by atomic number. I think they really got that pattern. And because of that, they saw the numbers start

over from the right and back to the left. And then they figured out the way that the atom's structured, why it did that. So I think using the patterns, looking for those in the periodic table gave them a much better understanding than my students in the past.

In summary, Richard helped students to find patterns in elements in the periodic table by themselves and also talked about the benefit of the teaching practice to help students understand the patterns.

Teresa also gave students opportunities to find patterns in data by themselves after the intervention more than before the intervention. Before the intervention, she explained scientific explanations before assigning experiments. Even when she taught inquiry-based lessons, the purposes of her three inquiry lessons were about to help students understand scientific explanations or models rather than to help students find patterns in data. After the intervention, she gave students chances to find patterns in data about earthquakes and volcanoes (3 of 3 investigations) and develop their explanations about the patterns. She asked students find relationships between locations of volcanoes and plate tectonics, three types of volcanoes and their locations, and the locations of earthquake and plate tectonics. During one of the three investigations, she asked students to share their ideas of patterns. In summary, Teresa had students find and share patterns in data after the interventions.

Finally, Dan intentionally helped students to find patterns in data after the intervention more than before the intervention. Before the intervention, he did not use the term 'pattern' in class and he was inconsistent in asking students to analyze data. He only asked students to find differences in experiment conditions in two of four inquiry lessons. However, after the intervention, he used the term 'pattern' in class and asked students to find patterns in data in 3 of 4 inquiry lessons. For example, after students tried to make bulbs lights in the three experimental conditions—one bulb and one battery; one bulb, one battery, and one wire; and one bulb, battery and two wire—he asked students to write their answers on the following two questions: "What patterns do you notice? What do you notice MUST happen in order for the bulb to light?" These two questions were newly added to this year's curriculum materials.

During the post-interview, he stated the importance of finding patterns in science: "I hadn't really put the pattern piece in and I'm seeing that that's an extremely important thing." He added that it is important to find patterns in data because it can "make a stronger argument", "make [a] conclusion or correlation better", "apply better", and it is a "repetitive nature of experimentation." In summary, Dan developed his practice of helping students find patterns in data and he understood the importance of finding patterns in scientific practices after the intervention.

Overall, the three teachers focused on making patterns explicit after the intervention more than before the intervention. They asked students to find patterns themselves and to share their ideas about patterns. In addition, two of them clearly talked about the importance or benefits of making patterns explicit in science or science teaching.

Provide opportunities for applications

The three teachers focused on helping students apply scientific knowledge to new situations after the interventions more than before the intervention. In addition, the application activities related more to real-world situations.

Richard showed a moderate change in using the practice of providing opportunities for application after the intervention. He used application questions related to real-world situations after the intervention. He asked students to apply what they learned in the acid and bases unit to understand phenomena related to their everyday lives or real-world situations. For example, he asked students to apply knowledge of neutralization reactions to new phenomena.

However, some of his application activities still seemed to focus on helping students understand the school's learning goals rather than using the knowledge in their lives. In his class, he wanted students to use what they learned to understand the knowledge better or understand another science topic. For example, he had students make three-dimensional model of an element in order to understand the atomic structure better. In addition, he also said that "using the periodic table in the next unit with chemical changes. They were able to apply what they learned and that made understanding [of chemical change] a lot easier." Overall, while Richard still had big concerns in helping students understand school learning goals, he used some activities to help students apply science ideas to real-world situations after the intervention.

Teresa increasingly used application activities related to real-world situations after the intervention (2 times before in intervention to 5 times after the intervention). Before the intervention, there were two application activities whose functions were to help students use knowledge to understand the knowledge better. For example, students were required to calculate densities of four unknown liquids. However, after the intervention, especially when she taught about volcano and earthquakes, she provided students with opportunities for application of knowledge to real-world situations. For example, students used knowledge of relationships between the location of earthquakes and plate tectonics to predict which cities in the world are likely to be affected by earthquake activities. They also had to research the effects of specific volcanoes on the communities near the volcanoes. In summary, Teresa increasingly used application activities after the intervention and the application activities related to real-world situations.

In Dan's class, the number of application activities in class before and after the intervention was the same. However, he put focus on helping students apply scientific ideas to their everyday lives after the intervention more than he did before. Before the intervention, there were three application activities. Two of them were about practicing their scientific knowledge in a new situation, such as pictures from magazines not necessarily related to students' everyday lives. In the other lesson, he focused on showing real-world examples, but gave some explanations rather than have students apply scientific explanations. However, after the intervention, application activities or questions were closely related to their lives. For example, after students found patterns between conductors and insulators, he asked students to write their answers to the question, "Would you use a conductor or an insulator to protect you from a shock? Explain." In other examples, he gave some students materials to make their own flashlights and he had all students to make a game using a bulb, a battery, and wires, where the bulb gave off light if students correctly connected questions about Michigan history and the answers.

During the post-interview, he stated his desire to help students apply scientific knowledge to their lives as the goal of his science teaching while during pre-interviews he did not talk about it as the goal of science teaching. During post-interview, he said, "I really want the kids to be able to apply the science that they're learning to their everyday life – to make it applicable. So that they can understand it and be able to use it." He also added that he wants students look at the world in a new way and application of scientific knowledge make the learning of it [science] important.

> Interviewer: You say your goal is to apply science to their lives. What do you mean by 'use the science' that they learned in their everyday life?
>
> Dan: If they learn something about electricity, say, that they can go out and they can see that this is what they're learning about and this is why, say, a switch works, or why if a certain area of the house is dark, they know there's a broken circuit ...
>
> Just for them to be able to look at the world in a new way and understand that there's more to the world than just that it's been there....Things they're learning about can help them understand how things work.... Make [a] connection with their everyday life. What they're learning in class, they can connect it and therefore make it important."

In other words, Dan not only helped students apply scientific knowledge to their everyday lives, but also expressed the importance of the practice for students' learning.

Overall, the teachers focused on helping students apply scientific knowledge to new situations after the interventions more than they did before the intervention. In addition, the application activities related more to real-world situations. While Dan talked about the importance of helping students apply scientific knowledge to their everyday lives, Richard still focused on applying science knowledge to new situations to understand it better.

Make the relevance of the topic to students' lives explicit

The teachers explicitly related science to students' everyday lives, especially at the beginning and end of their units after the intervention. Rather than explaining the importance of learning science from a scientist's perspective or for students' future jobs, they discussed the relevance of the topics to student's lives and gave several real-world examples.

Richard made several efforts to make the relevance of the topics to students' everyday lives explicit after the intervention. Before the intervention, he did not focus on relevance of science topics to students' everyday lives to motivate students to learn the topics. Instead, he talked about the importance of learning science for future jobs or tests or the importance of scientific practices from a scientist's perspective. After the intervention, he designed and implemented several activities to make the relevance of the topics about chemical change to students' lives explicit. At the beginning of a unit covering atoms and The Periodic Table, he discussed how atoms are useful in our daily lives and how an understanding of atoms is important. He also showed real-world examples of elements used in daily products such as Ammonium Lauryl Sulfate, which makes shampoo sudsy. Finally, he asked students to bring products used in their homes to class, to do research about elements in them, and explain how the products make their lives better and how understanding atoms is important.

After those efforts to establish the relevance of atoms to students' lives, he talked about the effect of those efforts on students. After the discussion on how atoms are used in our daily lives, he stated that his students had a better understanding of how important an atom is. He also expressed that the home product research would be "an eye-opener" for them to learn about atoms.

> We watched the Bill Nye and we talked about how atoms are in everything. A lot of kids seemed to think, "Wow, it's in everything." I think they got a better understanding of how important it is because of our discussion of how much we rely on products that are made from elements that we need to understand how the atoms and those element s combine to get the product. I don't think they fully understood, but maybe they will. It was a pretty good conversation yesterday about how much we use chemistry in our everyday lives and we don't even realize it. So it was a good discussion yesterday. (Interview on the day after the discussion on atoms)

> Many students seemed to get the idea of the elements combining to form compounds and this helped engage them in finding out more about what the other ingredients did. However, it seemed that some students didn't really care about

> what the ingredients did. But, for the most part, students began to see that elements were all around us and used in everything they brought in. *I think that many students could see the point of the assignment and began to understand that understanding elements and how they combined to make useful products was important.* But, with limited knowledge about elements and compounds, I don't think they fully grasped the true relevance of elements. However, it was at least a start. (Post interview with Richard)

It is worthwhile to note that during the pre-interviews, Richard expressed reservations about making the relevance of the topics of chemical change to students' lives explicit. He said, it is hard to "incorporate into their why I have to learn it [chemical change] attitude" and "I don't know if it's very motivating!" During the intervention for teacher development, he brought his lesson plan to teach atoms and the periodic table. After I suggested that he think about how to relate the lessons to students' everyday lives, he included several activities such as whole class discussion on atoms' use in our lives and individual research about elements used in home products.

When he taught about acids and bases, he also made efforts to relate science to students' lives. For example, in class he talked about why measuring pH and knowing the appropriate pH in water tanks and swimming pools would be helpful to our lives. He also talked about the effects of acid rain in our lives.

In summary, after the intervention, Richard more explicitly related science to students' everyday lives by discussing the relevance of the topics to student's everyday lives, giving real world examples, and having students find real world examples. During the post-interview, He also said that the practices were helpful for his students to understand the relevance of topics to their everyday lives.

Teresa increasingly gave students chances to think about reasons for learning about science after the intervention whereas she did not discuss the relevance of science to students' lives before the intervention. She did this three times after the intervention. For example, she asked "why is it important to know about earthquakes?" or "Why do we do it [an activity on volcanoes] today?. Students answers were "for high school", "[for a] test", or "teacher should teach it" rather than relating the topic to their lives. After listening to the students' answers, she ended the discussion with short comments such as "you don't want to decide to live close to volcanoes" or "to determine where to live". Regarding students' negative responses to her questions, she told me that it was hard for students to understand the importance of science to their lives because they were young. In summary, she tried to discuss the relevance of the topics to students' lives after the intervention, but during the discussion, her students did not seem to relate science to their everyday lives.

Finally, Dan explicitly discussed the relevance of the topic to student's everyday lives after the intervention. Before the intervention, although there were some cases for which he gave real-world examples on erosion, he did not have students think about the relevance of the topic to their everyday lives. However, after the intervention, he made several activities for students to think about the relevance of science to their lives. For example, he began the electricity unit, having students remember a time where they were in a blackout and what they couldn't do because there was no electricity. He asked students to write about their experiences during the blackout. He asked the questions, "What did you do differently? What couldn't you do anymore? [and] How did you have to change?" In addition, he used a story about a shipwreck to make the need for learning about electricity realistic. At the end of the unit, he did a class discussion on a question, "is electricity important to know about?". Students said electricity was important because they used electrical materials and that they could use their knowledge about electricity when they were in a blackout. The following is an excerpt from a class discussion.

> Dan: We do a lot of things in science and I want to know what do you think about it, Is electricity (E-) important to know about. Raise your hand if you think yes, (most students raised their hands). Raise your hand if you don't think that E- is very important to know about.(2 students raised their hands). So, Most you think E- is important to know about. Let's think about it just a second. Why is it important for us to be able to know about E-?
>
> ....
>
> Student 1: because in winter it is very cold, E- makes heat
>
> Dan: E-makes heat and we need it and it is important to know about that. OK. That's interesting. All right.
>
> Student 2: ..(Sound was not clear)
>
> Dan: we need fan to cool down. And you use E-.
>
> Student 3: it's good to know about it because when it blackout something, you may know make a E-.

Dan: that's something that I think really important. If we have a blackout, and we didn't have regular electricity, we now know how to make E- because you guise know about it. Good. Good idea.

Student 4:… some people don't know about E-, and we know how to make E-, and…..

Dan: we can help out financially, you can earn money, If people forget how to make E-, and you can remember, you will build up.

Student 5: I was blackout yesterday in the basement. All the upstairs run but, in the basement it was not because heating things were hotter and all the E- were gone.

Dan: so, they went out in the basement. So, what did you do, you learned something about E-, Did you tell about what happened your mom?

Student 5: she was totally wrong.

Dan: she was scared?

Student 5: she just hacked and …

Dan: OK, so, why is it important to know about E- then? It's a great story. But why is it important?

Student 5: There were wires in the last time….(sound was not clear)

Dan: So the wires came apart? So, was what kind of circuit?

Student 5: um,, open circuit.

Dan: so you put down together it can be,

Student 5: closer

Dan: so, do you have that complete circuit. So, you knew what happen when plugged up, you don't have complete circuit. Cool!

In the class discussion, Dan asked students to explain their reasons for why they thought learning about electricity was important. When one student (Student 5 in the excerpt) shared his experience on broken circuits in his basement, Dan asked why it was important to know about electricity and helped the student use scientific languages such as 'open circuit' to explain his experience at home. In summary, primarily at the beginning and end of the unit, he tried to help students understand and talk about how learning about electricity was important to their lives.

In conclusion, teachers made several efforts to make science relevant to students' everyday lives. In some classes, students seemed to understand the relevance of science to their lives, but in other classes, it was hard for the teacher to help students relate science to their lives.

Catch and hold students interest

Richard and Dan used a different kind of practice to catch and hold students' interest after the intervention. Before the intervention, they made some efforts to make science interesting, mostly providing opportunities to engage in hands-on activities or using games, simulations, humor or other fun features. After the intervention, in addition to doing these things, they modified the design of learning activities to include features that would enhance the appeal of the activities. Especially, they told interesting stories related to the topics that they would learn and allowed students to project themselves into situations. Through the stories, the teachers established questions for following inquiry activities or projects.

Richard created a context for his students to be motivated to participate in learning activities in the unit of atoms and the periodic table. Before teaching The Periodic Table, he introduced a story to make a context in which students had to make their own periodic table (See table 4.7 for the story). He had his students pretend that they would be the people to make a periodic table before Dmitri Mendeleev.

During the intervention, he said that he would use stories to "give them more purpose of the research" because using a story may be better than just stating, "Here is a research project and you need to find it." However, when he introduced the research project with the story, he had a challenge that his students were not interested in the story because the periodic table has already been done. Therefore, he elaborated upon the story with the history of science, explaining that many scientists tried to develop their own periodic table in the late 1860s, but Mendeleev got credit because he made predictions on elements based on his organization of elements and the predictions actually turned out to be true. In summary, Richard also used a story to make science interesting and motivate students to participate in class activities. However, he had a challenge in using a story in science class, and he solved the problem using his background knowledge of history of science.

In Dan's class, at the beginning of the electricity unit, he told a story about being 'shipwrecked without electricity' to make a situation in which students had to make an electric light to send an SOS, a signal to the other ship to save them (See table 4.11 for the story). This story has many features to catch students' interests such as going to Viet Nam (one of the students from his class were from Viet Nam), finding treasure, or having no delicious foods to eat, and making an SOS signal. In addition, he turned off lights and had them write about their answers to the questions about electricity by the overhead projector illumination in order for it to be more realistic.

This story was told to students after they wrote about their experiences where they did not have any electricity in the spring of 2008. After students understood the relevance of electricity to their lives through remembering experiences in a blackout, the story created a context for them to make bulbs light. After telling this story to students, he asked two questions, "How can we make the bulb light? What materials are appropriate for making the bulb light?" The next day, he and his students did an investigation of making bulbs lights up with a battery, a bulb, and wires. At the beginning of the investigation, he reminded students of the shipwreck story in order to motivate students to participate in the investigation.

He did not use these kinds of stories in his science class before the intervention. During the intervention, when I told him that we might use stories to catch students' interests in scientific activities, he stated that the investigation of making bulbs light up was itself interesting, but a story could make a context for the investigation. In class, when he told the story and had students write answers to the two questions related to electricity, his students were very engaged in writing their answers and each student wrote almost one-page answers. During the post-interview, he stated three benefits of using the story: it was engaging; it provided students with a reading and writing format and it could be used as a pre-assessment (He assessed students' ideas about how to make bulbs light up and what materials are needed). Beyond the benefits of motivating students to participate in scientific activities, he found another two benefits as an elementary teacher who needed to find out students' prior knowledge and to teach literature as well as science.

In summary, Dan tried to use a new motivational practice to make science interesting. He used a story to allow students to project themselves into a new situation where they had to make bulbs light up. Students liked the story and thought about various ways to make bulbs light up. He found several benefits of using stories in science class.

In conclusion, after the intervention, two teachers modified the design of learning activities to include features that would enhance the activities' appeal. In particular, they told interesting stories related to the topics that they would learn and allowed students to project themselves into hypothetical situations. Through the stories, the teachers established questions for following inquiry activities or projects.

Other practices that did not increase or change

There was no substantial change in teachers' use of four practices: providing experiences with phenomena, provide explanations, support students' autonomy, and know students and use knowledge about students. First, after the intervention teacher provided experiences that are appropriate for learning goals, as teachers did before the intervention. Richards and Dan continued to provide experiences with phenomena after the intervention. Teresa provided second-hand data for helping students understand volcanoes and earthquakes.

Second, teachers provided explanations through a lecture format or students' book reading but they still did not explicitly give students chances to compare and revise their ideas with scientific ones after the intervention. Although Dan asked students to share their ideas after several inquiry lessons about electricity, he did not challenge students with scientific ideas during the class.

Three, regarding motivational practices of supporting students' autonomy, the frequency of using the practices increased in two classes but it did not seem to be a big enough change to be counted as a pattern across teachers. Dan gave students more opportunities to solve problems in their own ways rather than insisting on a single method after the intervention. For example, he had his students figure out how to make bulbs light up or motors spin. Teresa used some practices that support students' autonomy. For example, she gave students an opportunity to solve problems in their own way. She had students research about the effects of volcanoes on communities near the volcanoes. She also gave students choices about what project they would do. However, she also used other practices that might undermine their autonomy after the intervention. She talked more about grades in her class, which might lead students to focus on performance rather than learning of science.

Finally, after the intervention, teachers continued to assess students' prior knowledge. They also tried to relate science to students' everyday lives and there were a couple instances that teachers considered students interests when designing and enacting their lessons. For example, Teresa said that she enacted a lesson about volcano using some chemicals such as vinegar in order to model volcanoes' eruptions because her students were interested in the modeling activity. However, I did not notice any substantial change in how they use knowledge about their students to enhance students' valuing of learning science.

Summary and Discussion

Summary

There was a modest change in teachers' teaching approaches thought teachers used several features of MIAIM in their science lessons. During intervention, I encouraged Richard to help students to find patterns in elements in the periodic table and use more motivational strategies as well as I explained MIAIM. After the intervention, Richard incorporated some features of MIAIM. He taught the periodic table with an inquiry approach and had students find patterns in data. The sequence of activities about the periodic table met all steps of MIAIM. When teaching other topics, he used a combination of didactic and hands-on approaches but he constantly established a central question for hands-on investigations, and applied scientific explanations to new situations. Regarding motivation he designed and enacted several activities relating science to students' everyday lives. In addition, he used a story to make a context in which students had to make their own periodic table.

During intervention with Teresa, I explained MIAIM and before her teaching, I sometimes asked to use some practices of MIAIM. After the intervention, Teresa's teaching approach did not change substantially. She used a didactic approach to teach plate tectonics. However, she had more inquiry and application lessons that fit the intent of MIAIM after the intervention than she did before the intervention. She consistently posted central questions for investigations, asked students to find patterns in data, and used many application activities. She also made more efforts to make science relevant to students' lives explicitly after the intervention.

During intervention with Dan, I explained MIAIM, commented on his worksheets used in previous years, and asked him to use more motivational practices. After the intervention, Dan used an inquiry approach for teaching science and used many aspects of MIAIM in his inquiry lessons. He consistently established central question for investigations, helped students find patterns in data, and asked students to apply scientific ideas to new situations. In addition to doing these practices, he talked about the importance of finding patterns in science and helping students apply scientific ideas to their lives. He also revised his worksheets used in his lessons. Regarding motivational practices, he used practices to relate science to students' lives. He also used a story to make a context for hands-on investigations and after using the story, he elaborated the benefits of using the story to student's learning and motivation.

Overall, the intervention using MIAIM seemed to help teachers use some practices such as posing central questions for investigations, finding patterns in data, applying scientific ideas to new situations and relating science to students' lives. However, there was no substantial change in teachers' use of some practices such as supporting students' autonomy, knowing students, and using knowledge about students.

Discussion

The results from this study showed that after professional development intervention using MIAIM teachers used some MIAIM practices to help students participate in scientific practices including inquiry and application, and to help students be more motivated to learn science. There are three important points related to findings about changes in teaching approaches and practices: teachers' learning and MIAIM, reasons for individual differences among teacher's use of MIAIM, interpretation about practices that did not change after the intervention.

Teacher learning and MIAIM. The results show that MIAIM can be used as a tool to help teachers use some teaching practices for scientific inquiry, application, and motivation with the support of professional development. In chapter two about literature review of this study, I introduced a model of teacher learning useful for understanding outcome of this study. In the model showed components of teacher learning over three different time intervals. At time 1, teachers interpret new knowledge and practices through their existing knowledge and practices and learn new ideas and skills by participating in professional development (PD) activities. The PD activities influence what teachers learn, but what teachers already know and do influences the interaction with teacher educators during the PD activities. In this study, during the PD activities using MIAIM, I tried to help teachers synthesize ideas about reform-based science instruction and value aspects of motivation by discussing important components of scientific inquiry, application, and motivation. I also commented teachers' curriculum materials or activities that fit the intent of MIAIM. Teachers might interpret MIAIM and my comments based on their existing knowledge and practices.

At Time 2, teachers enact the curriculum materials or class activities talked about during PD activities. In this study, teachers practiced planning and teaching science lessons that fit the intent of MIAIM. They established central questions for investigation, and provided experiences with phenomena, helped students to find patterns in data by themselves. They also explicitly related science to students' everyday lives and some of them used stories to make contexts for scientific investigations. Two of the three teachers said that they would continue to use some MIAIM practices. For example, Richard expressed that he would use similar lesson plans to teach the periodic table focusing on finding patterns in elements in the next year. Dan also expressed that this year's worksheet format was more scientific that those of his previous years' worksheet and would use them later. In other words, teachers incorporated some aspects of MIAIM in their science lessons.

At time 3, teachers transfer their new knowledge and practices to teach different curriculum materials. The application of the knowledge and practices is also influenced by the features of the curriculum materials, their students, and other contexts. In this study, when I phased out my support and teachers taught different topics and lessons, they still used some of MIAIM practices. For example, when Richard taught other topics, he used a combination of didactic and hands-on approaches but he continued to establish a central question for hands-on investigations, helped students apply scientific explanations to new situations and related science to students' everyday lives. Teresa enacted inquiry lessons that fit the steps of MIAIM. Finally, Dan designed a new worksheet when teaching about motor, and the lesson fit the first three steps of MIAIM. These result shows that teachers had been learning to teach science lessons that fit the intent of MIAIM whose goals are to help students participate in scientific practices and enhance students' valuing of learning science.

Reasons for individual differences among teacher's use of MIAIM. The result shows that some teachers use more aspects of MIAIM than the other. Several factors might have influenced their use of MIAIM: teacher's initial goal and teaching approaches; experiences with using MIAIM in their class; the content area; and school contexts. In the next paragraph, I will explain each factor with evidence from the results.

First, teachers' initial goals, teaching approaches, and practices seemed to influence their use of MIAIM in their lessons. In this study, depending on their initial teaching approach and practices, the teachers embraced either many or some aspects of MIAIM. Dan's initial teaching approach and goals in teaching science were most similar to the goals of MIAIM. Before the intervention he used an inquiry approach and tried to teach science 'as scientists do' their research. He also worked as a research scientist. However, for the other teachers, scientist's science was not of primary concern. They tended to focus on teaching scientific explanations rather than helping students participate in scientific practices. After the intervention, Dan incorporated more aspects of MIAIM than the others. More than the other two teachers, the sequence of his lessons consistently fit the intent of MIAIM.

Just as children's learning occurs within the 'zone of proximal development' (Vygotsky, 1978), teachers seemed to have their zone of proximal development in their learning to use MIAIM to teach science. Knowledge and practices presented by MIAIM is domain specific. Some teachers, who have similar goals and approaches to those of reform-based science teaching and want to help students appreciate their learning, may use MIAIM to design class activities more frequently than others. Steps and descriptions in MIAIM may give them guidelines for accomplishing their goals for teaching science.

However, teachers whose goals for teaching science are somewhat different from those of MIAIM may not see the affordances of using MIAIM and not frequently refer to it when planning and teaching.

Second, teachers' experiences with using some features of MIAIM might have influenced their judgment of the utility of MIAIM and their next trial of the practices. There is some evidence supporting this theory from teacher interviews and class observations. For example, both Richard and Dan used stories to make contexts for their following class activities. Richard used a story to give students the purpose of an element research project. He had his students pretend that they were scientists to organize a periodic table. However, his students seemed not to be interested in a story and he had to explain the history of science related to the development of the periodic table. Dan also used a story about being shipwrecked to make a context for students to make a bulb light up. His students were very engaged in the story and wrote their answers to questions about what materials they need to make a bulb light up. After implementing lessons using stories, Dan expressed his idea about the benefits of using stories in science class to students' learning and motivation, and used the story again at the end of the electricity unit as a post-assessment. However, Richard did not explain the benefits of using stories and did not use the story again like Dan.

In another example, all three teachers had class discussions about why learning science topics is important or relevant to their lives. In class discussions, Richard and Dan seemed to find evidence that students understood the relevance of the topics to their everyday lives and satisfied with the class discussion regarding the relevance, but Teresa did not. After class discussion, Richard told me that his students seemed to understand how atoms are related to their lives. He said, ""Many students seemed to get the idea of the elements combining to form compounds and this helped engage them in finding out more about what the other ingredients did...For the most part, students began to see that elements were all around us and used in everything they brought in." In Dan's class, his students explained why learning about electricity is important to their lives and they gave specific examples for the reasons such as using their knowledge when they were in a blackout. However, in Teresa's class, students did not relate the topics of volcanoes and earthquakes to their lives. Richard talked about the effects of class discussion on students' understanding of relevance of the topics to their lives and he had this kinds of discussion when teaching about acids and bases. However, Teresa expressed it was hard for students to understand why individual science topics were important to their lives because of their level of maturity[8].

In other example, Richard helped students find patterns in elements and make their own periodic tables. He found that students easily understood the explanations of atomic bonds because they understood the properties and patterns of elements in The Periodic Table. He said, "Like with sodium and chlorine, they [students] were able to identify right away because of the groups they [the elements] were in, how many electrons they have in their outside shell, and that helped them figure out much faster why those two combined in a reaction form. So I think they [students] were able to apply what they learned about the patterns and identify quickly the number of electrons and figure out why those two come together." During the post-interview, he also said that he

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[8] The findings regarding students' valuing of science support this claim, too. Richard's and Dan's students became more appreciative why learning science is relevant or important to their lives and Teresa's students (See chapter five for more results).

would use this kind of lesson in the next year again while he would revise it some for students to be able to find easily patterns in elements.

All these examples show that if students reacted positively to the teachers' new instructional and motivational practices in terms of their participation in class activities or understanding of scientific ideas, teachers tended to judge that new practices were useful in their teaching and they used or wanted to use these practices later. The relationship between teachers' learning of teaching practices and knowledge, and their student's reactions to new teaching practices is also supported by Marx, Best, and Tal's (2003) model of teacher learning. In their model, teachers' knowledge, beliefs, and attitudes are formed interactively with class enactment and each can influence the other. Student performance also influences teacher knowledge, beliefs, and attitudes, mediated through enactment. As they teach, teachers intuitively look to their students for feedback about the instruction. This information forms a key component of the feedback loop that shapes teachers' beliefs about their students and their own teaching (Richardson, 1996).

Third, the features of the science content area that teachers had to teach seemed to influence teacher's use of MIAIM. The features of the content area seemed to include the amount of or difficulty in scientific explanations that students have to understand, availability of hands-on activities for students to participate in, or easiness in relating science to students' lives. First, Richard and Teresa expressed the relationships between doing inquiry lessons and features of scientific explanations. For example, during pre-interviews, Richard showed reservation about doing inquiry lessons about physical and chemical change by saying that there is too much 'technical' information that students had to acquire. He said that using an inquiry approach to teach these topics might be possible but it would not be easy. Teresa also said, “it's hard to develop an investigation around a subject students are not familiar with.” Teachers’ these judgments about scientific topics might have influenced their decision to doing MIAIM based lessons or not.

It also seemed to be easier for teachers to incorporate hands-on investigation into some contents rather than other contents. After the intervention, Richard used more hands-on activities when he taught acids and bases than when he taught about atoms. He also said "when I was looking at thinking of doing something for nuclear, there was a real lack of student’ hands-on activities where they could explore and investigate.” Similarly, Teresa used several hands-on activities when teaching volcanoes and earthquakes. She was able to access real data about volcanoes and earthquakes for students to find patterns. In addition, it seemed to be easier for teachers to relate science to students lives in some contents rather than other contents. For example, during pre-interviews, Richard said that it is easier to relate topics of earth science such as thunderstorms or tornadoes to students’ lives than the topics about chemical and physical changes. Actually, his lesson plan about chemical change did not include any motivational strategies to relate science to students’ lives. After my suggestions, he designed some activities to make the relevance of topics to students’ lives. Similarly, Teresa said that some topics such as severe weather are easier to connect to students’ lives rather than others such as properties of matters. Overall, the features of science content seemed to influence teacher’s use of inquiry or other motivational practices.

Finally, school and classroom contexts including features of students seemed to influence teachers’ use of MIAIM. In the study, Teresa showed less change in her using of MIAIM practices than the other two teachers. When this study was conducted, her school was less stable compared to the other two teacher's schools. There were two school-wide schedule changes during semesters, one of which changed members of students in her class. In addition, she had less time to teach science than the other two teachers. She was busy due to her administrative work related to the school-wide schedule changes and the school's request of doing something not related to teaching science in her class. Instead of her, another teacher sometimes taught science in her class while she was doing administrative work. In this context, it seemed not to be easy to try new teaching practices. In addition, her students seemed to differ from the other two teachers' students in terms of their level of poverty, academic scores, stable school environment and so on. For example, the percentage of eligible students for fee or reduced lunch from Teresa's school was highest among the three schools (71% from Teresa's school compared to 25% from Richard's school and 54% from Dan's school) (http://www.greatschools.net). In addition, based on its state test result, Teresa's school received a GreatSchools rating of 3 out of 10 while Richard's school received a rating of 7 out of 10. In other words, students from Teresa's school receive poorer scores at MEAP test compared to the students from Richard's school. These different features of students might have influenced interactions of them and their teachers, and might also have influenced the teachers' judgment of the utility of MIAIM practices.

Interpretation about practices that did not change. The result shows that there is no change in teachers' use of some practices. In this section, I will discuss about each practice that did not change.

Regarding practices of providing experiences with phenomena, teachers already tended to use hands-on activities before the intervention. Richard and Dan continued to provide experiences with phenomena that are appropriate for learning goals. Therefore, it is not surprising that they continued to provide experiences with phenomena after they participated in the intervention that intended to help teachers to use hands-on investigation.

In addition, after the intervention, teacher continued telling scientific information. However, they did not give students opportunities to compare their ideas with scientific ones. I speculate that teachers might not use the practices because they might think that it is not necessary to have class discussion to compare students ideas and scientific ones if they told the information and assigned experiments. In addition, they might not just have time for class discussion to compare students' ideas with scientific ones. During the intervention, Dan said that that the discussion might be helpful but he had a challenge for doing hands-on activities because he had to teach other topics such as math and literacy. His saying might support the hypothesis.

Regarding supporting students autonomy, teachers did not use practices to support students' autonomy after the intervention. Other practices such as providing central questions or helping students find patterns in data seemed to be easy to do or easily understandable to teachers. However, the practices related to supporting students' autonomy seemed to be related to teachers' general teaching style or classroom norms. Teachers might be afraid of giving many choices to students in their classes or having them solve problems in their own.

Finally, there was no increase in teachers' use of their knowledge about their students. While MIAIM specifically explains about other three motivational practices including relevance of science to students' lives, making science interesting, or supporting students' autonomy, it does not give specific strategies for teachers to use their knowledge about students. In MIAIM, the motivational principle of knowing students and use knowledge about students is underlying principles for helping students value their learning of science. Therefore, teachers might not focus on the motivational principles when they looked at explanations about motivational practices of MIAIM.

Chapter Five: Findings and Discussions About Students' Valuing of Science, Efforts to Learn, and Understanding of Science Ideas

This chapter addresses my last research question which asked: What effect does an instruction based on MIAIM have on students' valuing of learning science, efforts to learn, and understanding of scientific ideas? Additionally, what features of the instruction may have played a role in these outcomes? I asked the question to determine whether and how the professional development experiences around MIAIM influenced students' motivation and their learning. I hypothesized that changes in teaching practices would influence students' motivation, especially, their valuing of learning science and their understanding of scientific ideas. I also hypothesized that changes in teaching practices and students' valuing of science would influence their effort in participating in class activities. To address my last research question, I draw on data analyses of surveys, class observations, and pre-and post-tests.

Valuing of learning science

In order to understand the influence of MIAIM-based lessons on student's valuing of science, I analyzed students' pre-and post-surveys. The analysis of the surveys shows that students who received the MIAIM lessons became more interested in science and better understood how science is related or important to their everyday lives. After reporting results about the students' overall changes in their motivation to learn science, I will report changes in students' views of whether they think science is useful, important, and interesting to them. Because two teachers used more aspects of MIAIM in their science lessons than the other, I will report the result by each class.

Overall change in students' motivation to learn science

At the end of the post-survey, I asked whether students thought their motivation for learning science had changed or not changed after the MIAIM-based lessons and why. The analysis of the students' responses to the open-ended question indicates that students' attitudes toward science had changed in a positive direction with some differences in results from different teachers' classes.

In Richard's class, 27% of students (4 of 15 students) reported that that their motivation to learn science has positively changed. The most frequent reason was that they understood how science is related to their lives (three students gave the reason). For example, one student wrote, "Yes, [it changed] I thought science really couldn't be used for everyday life, but now I know it can be." Another student wrote, "Yes, [it changed] because two months ago, I thought science was boring and if it had nothing to do with being a vet [veterinary]. I didn't care and didn't pay attention but now I realized all science can be interesting and should pay attention because it could help me with everyday situations." Another reason for positive change in their attitudes towards science was using hands-on activity in science class. One student wrote, "I feel better about science, but not because of what I learned, because of how I learned. This year in science we do more hands-on learning than reading out of a book learning. I feel that I learn better with hands-on things because it is more interesting." However, 53% of students' attitudes towards science did not change because 33% of them already liked science and 20% of them still did not like science. In summary, in Richard's class, there was a moderate change in students' interest in science. The students whose attitudes toward science changed attributed their change to their understanding of the relevance of science to their everyday lives and the use of hands-on activities in class.

From Teresa's class, 50% of students (5 of 10 students) reported that they became more interested in science. The most frequent reasons for the change were using hands-on activities and learning interesting topics. For example, one student wrote, "I learned interesting stuff this year and it was fun doing the experiments. Because my teacher made it a bit more fun to learn science. I especially liked to do the volcanic lab, it was fun watching the bubbles foam out." Another student wrote, "Yes, because now that we are learning about more interesting things, class is more interesting." However, 30% of students (3 of 10 students) reported that they became less interested in science because topics such as plate tectonics, earthquakes and volcanoes, "have gotten duller" and that they didn't think that the topics were necessary to learn.

In Dan's class, 65% of students (11 of 17 students) reported that they became more interested in science and that science was now more important to them. The most frequent reasons for the change was that learning about electricity and doing experiments about electricity was interesting, and that learning about electricity was important for their everyday life (Six of the eleven students responded this way). For example, one student wrote, "It [science] is more interesting because we made our own flashlight." Another student wrote, "Science is important and I am more interested in it because if you know about electricity, it can help you during you life. Like if there an open circuit." A third student wrote, "I find science more important now that I learned electricity. It has because I think electricity is important for everyday life." Only 25 % of students' (4 of

17) attitudes did not changed. One student said that her attitudes did not change because she already liked science. Overall, after students learned about electricity from Dan's class, many of them valued science more than before.

In summary, students from all classes reported positive changes in their valuing of learning science. There was a moderate change in students' understanding of the relevance of science to students' lives from Richard's class. There was also a moderate change in students' interests in science from Teresa's class. There was a substantial change in the students' interests or understanding of the importance of science in Dan's class. Across the three classes, Richard's and Dan's students became more appreciative of how science or electricity is useful to their everyday lives than Teresa's students. In addition, there was biggest change in Dan's students' motivation to learn science among three classes' students. Some of students from the three classes attributed their change to their teacher's teaching practices, such as using hands-on activities or labs, their learning about new topics such as electricity, or their understanding of the relevance of science to their lives. In the next section, I will report findings from the analysis of the survey about each value of learning science--utility, importance, and interest.

Utility value

The analysis of the students' responses to questions about the utility value of learning science is consistent with the results concerning the overall change in their motivation to learn science. Students from Richard's and Dan's classes showed an increase on their agreement to the idea of the relevance of science to their lives more than students' from Teresa's class. After describing results from the analysis of Likert scale items about everyday-related and job-related utility values of learning science, I will report the results from the analysis of students' responses to open-ended questions that asked, "Do you think science is useful? What parts of science are useful to you? Why? What parts of science are not useful to you? or why not?"

Likert scale items. Likert-scale items were on a 7-point scale with 1 indicating "Strongly disagree" and 7 indicating "strongly agree." The analysis of student responses indicates that there was a significant increase in student agreement with the idea of everyday-related utility value of science between the pre-and post-survey in Richard's class while there was no change from Dan's and Teresa's class. Figure 5.1 shows the mean score of students' agreement with the idea of everyday related utility value of science from the three classes.

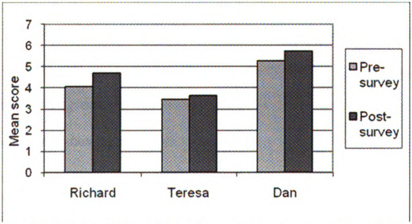

Figure 5.1. Students' valuing of learning science from a perspective of everyday related utility value

In the pre-survey, Richard's students were fairly neutral with the idea of the everyday-related utility value of science (M=4.05, SD=1.44) but significantly increased their valuing in the post-survey (M=4.7, SD=1.10) (t_{15}=2.270, p <0.05, σ = .59). This shows that students became somewhat more appreciative of how science is useful in their everyday lives. However, in other classes, there was no significant change in students' responses between the pre- and post-surveys. Teresa's students slightly disagreed with the idea that science is useful to their everyday lives in the pre-and the post-survey. Dan's students agreed with the idea in the pre-and post-surveys.

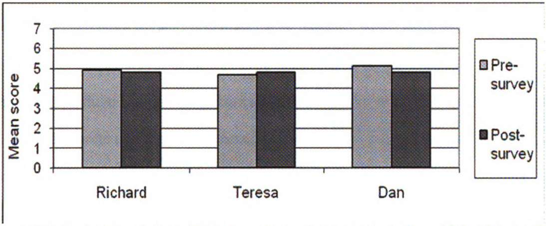

Figure 5.2. Students' valuing of learning science from a perspective of job related utility value

Regarding the idea of job-related utility value, students from each class slightly agreed with the idea that science is useful to their future jobs. Figure 5.2 shows the mean score of student agreement with the idea of the job-related utility value of science from each class. They showed no significant difference between the pre-and post-surveys. The result indicates that average students somewhat understood the job-related utility value of learning science and they did not change their views after MIAIM based lessons.

Open-ended questions. The pre/post survey asked open-ended questions about student's valuing of learning science from the utility value perspective. Data analysis of the students' answers to the question showed several results.

First, both in the pre-and post-surveys, students expressed that science is useful them for various reasons such as 'useful for everyday life', 'job', 'fun', 'learning [new ideas]' (See Table 5.1. for students' reasons why learning science is useful to them). Second, in Richard's class, there was no change in the reason why science is useful or not useful to them. However, fewer students described 'not useful' parts of science to them in the post-survey (60% of students in the pre-survey compared to 40% of students in the post-survey) and more students described useful parts of science in the post-survey (73% of students in the pre-survey compared to 86% students in the post-survey). Third, in Teresa's class, there was no change between the pre-and the post-tests on the number of students who wrote useful parts of science and/or un-useful parts of science. However, as the reason for the utility or inutility, more students described everyday-related utility value (20% of students in the pre-survey compared to 40% of students in the post-survey) and fewer students described job related utility value in the post-survey (60% of students in the pre-survey compared to 10% of students in the post-survey). Finally, students' from Dan's class increasingly reported that science is useful in their everyday lives (12% students in the pre-survey compared to 29 % of students in the post-survey). For example, in the post-survey, one student wrote, "All of it [science] is useful because it helps you in your everyday life." Another student wrote, "They are most all useful to you because you can have a blackout and use the stuff you learned to make electricity."

Table 5.1. Students' reasons for why learning science is useful or not useful

	Richard's class % (n=15)		Teresa's class % (n=10)		Dan's class % (n=17)	
	Pre-survey	Post-survey	Pre-survey	Post-survey	Pre-survey	Post-survey
Useful for every day life	26	26	20	40	12	29
Job	13	26	60	10	0	0
Fun, like, or love	6.7	0	0	10	18	12
Test, grade	0	0	0	0	5.9	0
Use them in the future	0	6.7	0	0	12	0
Learn scientific ideas	13	6.7	10	10	12	0
Waste of time/already learn	6.7	6.7	0	10	0	0
No reason described	20	26	0	20	29	18
Other (Ambiguous answers)	20	6.7	0	10	0	0

In conclusion, data analysis of students' responses to Likert type items and open-ended questions shows that students from Richard's and Dan's class understood why science is related to their lives more than Teresa's class after they learned science MIAIM-based lessons. This result is similar to students' reporting about their overall changes in their motivation to learn science. Students from Richard and Dan's classes attributed positive changes in their attitudes towards science to their understanding of how science is related to their everyday lives but Teresa's students did not. This may show that Richard's and Dan's frequent and in-depth use of practices of relating science to student's everyday lives influenced students' understanding of the role of science to their lives.

Importance of science

The analysis of students' responses to questions about the importance of learning science is consistent with the result from the analysis of students' overall change in their motivation to learn science. Of the three classes, Dan's students showed a significant increase on their agreement with the idea of the importance of science. After describing results from the analysis of Likert scale items, I will report the results from the analysis of students' responses to an open-ended question.

Likert scale items. The analysis of student's answers to Likert scale items indicates that students from Richard's class agreed with the importance of science and students' from Teresa's class slightly agreed with it in the pre-test. There was no significant change between the pre-and the post-survey from each of the two classes. Finally, Dan's students in the pre-survey agreed with importance of science (M=5.79, SD=1.28) and significantly increased their agreement with it in the post-survey (M=6.29, SD=0.64) ($t_{16}=2.287$, $p < .05$, $\sigma = .55$). This shows that students became more appreciative of how science is important to them as a result of the instruction based on MIAIM. Figure 5.3 show the mean score of students' agreement with the importance of science from each class.

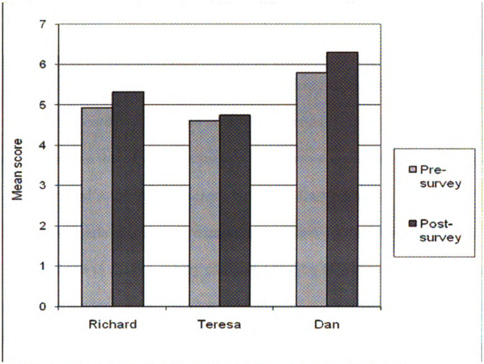

Figure 5.3 Students' agreement with the idea of importance of science

Open-ended questions. Data analysis of students' responses to open-ended questions about the importance of science shows three results. First, regarding the fields of science that students think important, in Richard's and Teresa's classes, there was no change in students' reporting on the field of science that they thought was important. From Richard's class, in the pre-survey no students mentioned that learning about the periodic table was important. In the post-survey one student wrote that learning about the periodic table was important to learn, but another student wrote that it was not important. Similarly, from Teresa's class, no students expressed that learning about plate tectonics is important in the pre-survey. In the post-survey one student wrote that learning about plate tectonics was important, but another student wrote that it was not important. However, Dan's students increasingly reported in the post-survey that learning about electricity was important (0% to 47 % students). For example, they wrote that "The most important thing about science…is that when you grew up and you want to make electricity, you can because you know how."

Second, the most frequent reason for why science is important was related to their future 'job', everyday-life related utility, or understanding of the world and how things work. Between the pre-and the post-survey, there was no difference on students' reasons form Richard's and Teresa's class. However, Dan's students increasingly reported that some parts of science are important to them because it was related to their lives (6% of students in the pre-survey compared to 29% of students in the post-survey). For example, one student wrote, "If your light go[es] out, you could fix it then." (See table 5.2 for the summary of data analysis)

Table 5.2. Students' reasons for why learning science is important or not important

	Richard's class % (n=15)		Teresa's class % (n=10)		Dan's class % (n=17)	
	Pre-survey	Post-survey	Pre-survey	Post-survey	Pre-survey	Post-survey
Useful for every day life	20	7	20	20	6	29
Job	33	47	30	20	6	
Fun, like, love	0	0			18	12
Learn new ideas	7	13	40	10		

In conclusion, students from Dan's class understood the importance of learning science, especially electricity, after Dan taught science lessons embracing many aspects of MIAIM. The MIAIM-based lessons seemed to positively influence their views about why learning science is important and what part of science is important. However, there was no big difference in students' understanding of the importance of learning science in Richard's and Teresa's classes, who taught science lessons using fewer aspects of

MIAIM than Dan did.

Interest value

The analysis of students' responses to questions about student interest in science weakly supports the result from the analysis of students' overall change in their motivation to learn science. After describing the results from the analysis of the Likert scale items about students' situational interest in science class and their general interest in science, I will report the results from the analysis of students' responses to an open-ended question.

Likert scale items. The analysis of the Likert scale items about students' situational interest in science class shows no differences in students' responses between the pre-and the post-survey from Richard's and Teresa's class. While Richard's students slightly agreed with it, Teresa's students slightly disagreed with it. However, there was a marginal increase on student's situational interests in science from Dan's class (M=5.48, SD=0.98 for the pre-survey compared to M= 5.79, SD=0.66 for the post-survey). Although the increase in students' situation interest in science did not reach statistical significance (t_{16}=2.09, p=.053>.05), the direction of the increase is consistent with the results concerning the overall change in their motivation to learn science. Figure 5.4 shows the result.

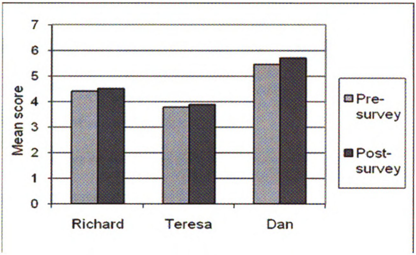

Figure 5.4. Students' situational interest in science class

In addition, the analysis of Likert scale items about student's general interest in science show that there was no increase in students' general interest in science between the pre-and post-surveys from each class. Richard's and Teresa's students were generally neutral with the items about individual interest in science in the pre-surveys. Dan's students agreed with the items about individual interest in science in the pre survey. There was no significant difference in their responses between the pre-and the post-survey in each class. Figure 5.5 shows the result.

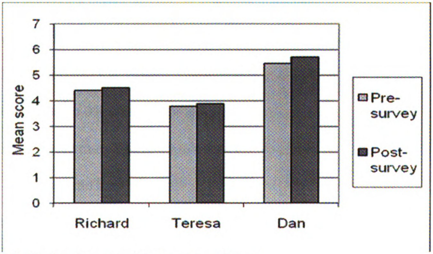

Figure 5.5. Student's general interest in science

Open-ended questions. Data analysis of student responses to open-ended questions about their interest shows three results. First, regarding the fields of science in which students are interested, in Richard's and Teresa's classes, there was no change in students' reporting on field of science that they liked. In Richard's class, 7% of students in the pre- and the post-surveys reported that they liked learning about atoms and the periodic table that he used some aspects of MIAIM to teach. In Teresa's class, none of her students made comments about plate tectonics in the pre-survey, and 10% of students in the post-surveys from Teresa's class reported that they disliked learning about plate tectonics after loosely based MIAIM lessons.. However, Dan's students increasingly reported in the post-survey that they liked electricity that he incorporated several aspects of MIAIM to teach (0% of students in the pre-survey compared to 29 % students in the post-survey).

Second, regarding ways of learning science, many students from each class reported that they liked doing experiments (See table 5.3 for result). There was no change between the pre-and post-survey from all classes (60 % to 73 % of students from Richard's class, 40 % to 50 % of students from Teresa's class, and 24 % to 24 % of students from Dan's class). However, students disliked 'reading books' and 'filling out worksheets.' It is worthwhile to note that Richard's students did not mention that they disliked the readings or worksheets in their post survey (20% of students in the pre-survey compared to 0% of students in the post-survey).

Finally, the most frequently cited reason for their interest in science was that science was 'fun' and they liked science. They also reported that they like experiments in class because they do something rather than just listening. The most frequent reason for their disinterest was 'boring.' There was no change between the pre-and post survey regardless of classes.

Table 5.3. Student's reports for the interesting or not interesting parts in science and their reasons for interest or the lack of the interest

	Richard's class % (n=15)		Teresa's class %(n=10)		Dan's class % (n=17)	
	Pre-survey	Post-survey	Pre-survey	Post-survey	Pre-survey	Post-survey
Frequently reported parts that students were interested or not interested in						
Experiment (interested)	60	70	40	50	24	24
Reading books (not interested)	27	20	10	20	0[9]	0
Writing (not interested)	20	0	10	20	18	6
Reason for interest or no-interest						
Fun, love	13	27	0	20	12	18
Doing something (see reactions, hands-on, easy to learn)	13	27	30	40	6	0
Boring	7	33	20	40	6	0

In conclusion, the data analysis of Likert scale items and open-ended questions about students' interest does not show any change in student's general interests in science and their situational interests in science class. There was only marginal increase in students' situational interests in Dan's science class and in their interest in learning about electricity. Overall, this shows that students from Dan's class became more interested in science after Dan taught science lessons embracing many aspects of MIAIM. However, there was no difference in students' interests in science or science classes from Richard's and Teresa's class, who taught science lessons using fewer aspects of MIAIM than Dan did.

Discussion

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[9] One student from Dan's class reported that she liked reading science books in the pre-survey.

There are important points resulting from the findings about changes in students' valuing of learning science: somewhat different results about increases in students' interests in science from Likert scale items and students' responses about overall change in their motivation to learn science, and relationship between teachers' use of MIAIM practices and students' changes in their valuing of learning science.

Interpretation about the results about students' interests. While students wrote in open-ended questions that their motivation to learn science had changed, and they became more interested in science, results from Likert scale items did not show significant increase in their situational interests and personal interests in science. There are several explanations about the differences of the result. First, there may be a ceiling effect in measuring the changes of students' interests in science when using Likert scale items. For example, the scores of 4 of 17 Dan's students about situational interests from Likert scale items were more than 6.5 out of 7. This may influence the small change in students' interests by the measurement of Likert scale items. Second, although students were more interested in their science class or specific topics such as electricity, there should be more help for students to substantially develop their individual interest in science. Literature on interest development support this explanation in that in order for students to develop their individual interests, their situational interests need to be triggered and sustained through several experiences (Hidi & Renninger, 2006).

Relationship between teacher practices and students' valuing. Students' changes in their valuing of learning science seemed to be closely associated with what kinds of practices of MIAIM teachers used and how frequently they used the practices. The patterns in the teachers' uses of practices and their students' changes support this pattern.

Richard used some aspects of MIAIM. Although his lesson on the periodic table followed the steps of MIAIM, the lessons did not significantly influence students' changes in their interests or views on the importance of science. However, he put forward efforts to help students understand how learning of atoms is important and atoms are related to their everyday lives. In addition, the survey results show that his students became significantly more aware of how science relates to their lives after learning about atoms and the periodic table.

Teresa used the sequences of MIAIM in her inquiry lessons and she tried to communicate the relevance or importance of leaning science to students' lives. However, her comments during class discussion were short and she did not do so as frequently as Dan or Richard. Her students did not seem to change their views on the relevance and importance of science to them after her instruction. Regarding student interest in science, there was a small change in her students' interest in science class. According to the students' writing on their overall change in their motivation to learn science, 50% of student wrote their attitudes toward science have changed. However, 30 of students wrote their changes were small. They wrote words such as "a little [changed]" or "kind of [changed]." And 20% of students wrote that they liked one experiment of making a model of eruption of volcanoes. Although she followed the sequence of MIAIM, she did not usually use hands-on experiments but used second-hand data about volcanoes and earthquakes.

Dan consistently followed the sequence of MIAIM, used hands-on experiments, and related science to the students' lives. In particular, he gave students many chances of doing experiments with a battery, a bulb, and wires, and he related the topic of electricity to students' lives by having them remembering their experiences in a blackout. These practices seemed to influence students' interests in science, especially electricity, and their understanding of the importance and the relevance of the electricity to their lives. Throughout the students' responses on the post-survey, the students pointed out that they liked experiments with a battery, a bulb, and wires, in their classes. In addition, they wrote that science is useful because they can make a closed circuit if there was a blackout, and so science is important.

However, across the classes, there was no significant increase in student's views about how science is useful for their future jobs, between the pre-and post-surveys. The no difference seems to be resulted from the fact that while MIAIM focus on the relevance of science to student's lives rather than job related utility value.

In summary, MIAIM-based lessons influenced students' valuing of learning science. In particular, this study provides evidence for the claim that changes in a teacher's instructional and motivational practices influence students' valuing of learning science. Students whose teachers used several inquiry lessons using hands-on activities tended to be more interested in science. In addition, students whose teacher made the relevance of science to their lives explicit seemed to become more aware of how science is related to or important to their lives.

Effort: Student's on-task and their perceived effort

In this section, I will report findings on the question of whether changes in teaching practices influence their students' level of participation in class activities. I hypothesized that changes of teacher's instructional and motivational practices might influence a student's level of participation in activities in science class. In order to understand the influence of MIAIM-based lessons on students' efforts to learn science, I draw on the analysis of the numbers of students who were on-task in class activities and survey about students' perceived effort to learn science in their class.

On-task students. The analysis of percentage of the numbers of students[10] who participated in class activities shows that students from Richard's and Dan's classes participated more in class activities when their teachers taught science MIAIM-based lessons. Figure 5.6. shows the percentage of the number of on-task students from each class before and after the intervention for teacher development. In Richard's class, the mean percentage of the number of on-task students increased from 66 % before the intervention to 77 % after the intervention. There was no increase in Teresa's class before and after the intervention. Finally, in Dan's class, the mean percentage of the number of on-task students increased from 74 % before the intervention to 80 % after the intervention.

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[10] In the Chapter three: Method, I explained how I measure the number of students who participated in class activity. For the readers, I summarize the way that I measured student's on-task. In order to measure the level of students' participation in science class, I checked the number of students who were on-task in class. Every 10 to 15 minutes or when class activities changed, I scanned the class and noted what students were doing, determining the proportion of students who were on task. I calculated the percentage of on-task students from every class and then, I calculated the averages percentage of on-task students from each teacher's class prior to and after the intervention in order to understand how MIAIM instructions influence students' efforts to participate in class activities.

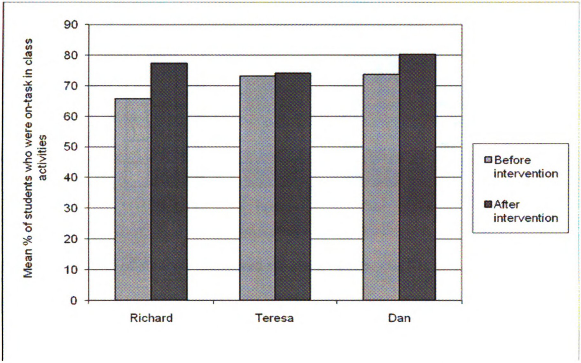


Figure 5.6. Mean percentage of the number of on-task students from each class

Perceived effort. In addition to measuring the on-task behavior of students, I analyzed Likert scale items related to students' perceived efforts in class activities. Likert-scale items were on a 7-point scale with 1 indicating "Strongly disagree" and 7 indicating "strongly agree." That analysis shows no significant difference between the pre-survey and the post-survey from each class. Students from Richard's and Dan's classes agreed with their active participation in class activities, and students form Teresa' class slightly agreed with it. Figure 5.7 shows the result.

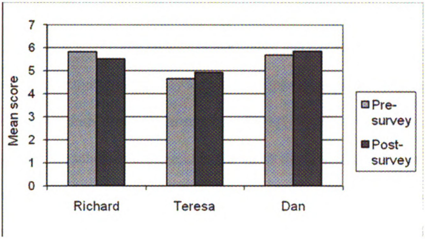


Figure. 5.7. Level of students' perceived efforts in science class

Discussion

The results from the analysis of the number of student's on-task show the possible relationship between MIAIM-based lessons and students' level of participation in class activities. More students from Richard's and Dan's classes participated in class activities when their teachers taught MIAIM-based lessons. There was no difference in the students' level of participation from Teresa's class before and after the intervention. I propose two explanations about the no differences in students' level of participation in Teresa' class. First, because Teresa used practices of MIAIM less compared to other teachers, her students did not show any change in their participation in classes while students from other classes more participated in class activities during MIAIM based lessons. This explanation support my hypothesis of my study that MIAIM based lessons have positive influence on student's level of participation. Second, although she used some aspects like the other teachers, students' participation was influenced by other factors. One possibility was related to the change of the students' class hour. Before the intervention, the students from her class learned science in their first hour. At those periods, they tended to be quiet and participated in class activities. However, after the intervention, there was a schedule change in her school and her students learned science in their fifth hour after their lunch. They tended to be less focused on studying than before. Teresa's comments during class supports this hypothesis. When students did not study in class after the schedule change, she told the students in class that her expectation to them did not change even after they learned science in their fifth hour. In summary, although there was no significant change related to students' level of participation in class activities from Teresa's class, the results from the other classes support some positive influence of the MIAIM-based lessons on students' level of participation in class activities.

Results from the survey did not show any changes in students' perceived effort in science classes between before and after their teachers' participation in the intervention for teacher development. There is one possible explanation for the result. The Likert scale items, measurement on students' perceived efforts to participate in class activity, may not have been good enough to measure students' behavioral efforts to participate in class activities. Even though students more participated in class activities, students did not perceive their changes.

In conclusion, although the results form Likert scale items, measurement on students' perceived efforts to participate in class activity, did not support my hypothesis for this study that changes in instructional and motivational practices might affect students' efforts to learn science. However, the results from the measurement on on-task behavior supports the hypothesis that MIAIM bases lessons have positive influence on students' effort to participate in science activities. I think that behavioral measurement would be better than perceived measurement to assess students' actual participation in class activities because what teachers look to as the feedback for their new instructional and motivational strategies seems to be students' behavior engagement in the class activities rather than students' perceived reports about their efforts.

Understanding of scientific ideas

My third research question regarding students asked how an instruction based on MIAIM affected students' understanding of scientific ideas. This question is important because teachers should help students learn scientific ideas, as well as be motivated for learning science. To answer the question, I drew on the analysis of the pre- and post- tests to assess student's understanding of scientific ideas. Because the teachers taught different topics, the test to assess student's understanding differed. In this section, I will report findings from data analysis of the pre-and the post-tests in each class.

Richard's class

The test to assess student understanding of scientific ideas form Richard's class included 10 questions about atoms and periodic tables (9 multiple choice questions and one open-ended question). In addition, in the post-test, there was one essay question asking students to write about how the organization of the periodic table helped them understand the elements. The analysis of 19 students from Richard's class indicated that students showed a gain in their knowledge about atoms and the periodic table with an average pre-test score of 26 % correct compared to a post-test score of 74.6% correct (t_{14} =5.833 , p <.01, σ = 1.52). After the MIAIM-based lessons, they learned scientific explanations about atoms and the periodic table. In the next paragraph, I will report findings about each test topic. Results on each test topic are given in table 5.4.

Table 5.4. Mean percentage correct for each test topic on atoms and the periodic table from Richard's class (n=19)

Test Topic (Total ten questions)	Pre-test (%)	Post-test (%)
Definition of Atom (One question)	40*	80*
Structure of Atom (Four questions)	35**	72**
Atom drawing (One question)	0**	86**
Feature of the periodic table (Two questions)	23**	90**
Interpretation of the periodic table (Two questions)	17**	60**

**p <.01; *p <.05 : These report the significance of the difference based on t-tests.

The analysis of individual test topics indicated that after instruction based on MIAIM, students more understood what atoms are (an average pre-test score of 40 % correct compared to a post-test score of 80% correct) and the structures of the atoms (an average pre-test score of 35 % correct compared to a post-test score of 72 % correct). They understood that atom is the smallest particle into which an element can be divided and still be the same substance. They also understood what neutron, electron, proton, and nucleus are. In addition, more students drew the structure of one element when they were given the atomic number of the element (an average pre-test score of 0 % correct compared to a post-test score of 86 % correct).

The analysis also indicated that after the instruction based on MIAIM, students understood the features of the periodic table better (an average pre-test score of 23 % correct compared to a post-test score of 90 % correct) and interpreted the periodic table correctly (an average pre-test score of 17 % correct compared to a post-test score of 60 %

correct). More students understood that the elements of the periodic table are arranged in order of atomic mass, and the number on the periodic table explains how many electron energy levels are in the atom. In addition, using the periodic table, they found out which elements were metals or nonmetals.

Finally, the analysis of student responses to one open-ended question in the post-test shows that students understood the meaning of the periodic table. All students wrote that the organization of the periodic table helped them understand the elements in the table. Of them, six students expressed that the table helped them understand the properties of elements such as how they are alike or different. Another six students wrote that the periodic table gives information about atoms such as electron level, atomic number, and mass, and that they can read the periodic table. Another three students wrote that through the table, they can understand what elements can react with which elements. For example, one student wrote,

> It [the periodic table] shows you how the atoms are alike and different from each other. It also shows what atoms would react together, and how a lot of the atoms that are near each other have similar properties.

In summary, students from Richard's class gained understanding about atoms and the periodic table after instruction based on MIAIM. In addition, they were able to explain that the periodic table gives them information about elements such as atomic mass, properties, and atomic bonding.

Teresa's class

The test used in Teresa's class had 6 open-ended questions about plate tectonics. Overall, the analysis of 15 students from her class indicated that students showed some improvement in their knowledge about plate movement, earthquakes, and volcanoes with an average pre-test score of 33 % correct compared to a post-test score of 67% correct (t_{14} =5.123 , p <.01, σ = 1.32). Results on each test topic are given in table 5.5. In the following paragraphs, I will explain the results on each test topic.

Table 5.5. Mean percentage correct for each test item on plate tectonics from Teresa's class (n=15)

Test Topic (Total Six questions)	Pre-test (%)	Post-test (%)
Cause of plate movement (One question)	0*	40*
Effect of Plate movement (One question)	77	90
Earthquakes and plate boundary (One question)	13**	66**
Effects of Earthquakes(One question)	53**	83**
Effects of Volcanoes(One question)	57	80
Types of Volcanoes(One question)	0*	40*

**p<.01; *p<.05 :These report the significance of the difference based on t-tests.

Plate movement. Students gained knowledge about the cause of the plate movement (an average pre-test score of 0 % correct compared to a post-test score of 40% correct). In the pre-test, students did not know what caused the plate to move although they learned the movement of the plates when they were in 6^{th} grades. The most frequent incorrect explanations for the plate movement were 'earthquake' (5 students) and 'rotation of the earth' (2 students). They had misconceptions that earthquakes, which were the result from the plate movement, caused the plates to move. In the post-test, 40% of students had correct explanations. For example, they wrote "the convection currents in the mantle causes movement of the plates." However, 60% of students still did not write correct explanations and some of them still had similar misconceptions that they had before. They wrote that some phenomena, such as earthquakes or sea-floor spreading, which are resulted from the plate movement, caused the plates to move.

There was no significant gain in student understanding of the effects of the plate movement in the post-test (an average pre-test score of 77 % correct compared to a post-test score of 90% correct). In the pre-test, many students wrote correct answers to the question of the effects of plate movement. The most frequent answers were earthquake (10 students) and volcanoes (3 students). In the post-test, students listed several effects of plate movements more than in the pre-test. Their answers included earthquakes, volcanoes, tsunamis, seduction zones, mountain ranges, and so on. However, there was no significant change between the pre-test and the post-test.

Earthquakes. More students understood the relationship between plate tectonics and the locations of earthquakes in the post test (an average pre-test score of 13 % correct compared to a post-test score of 66 % correct) On the pre-test, most of students did not have a correct scientific explanation of why some places are more likely to experience an earthquake than others. One frequent incorrect explanation was related to physical features of lands such as location, weather, or flatness of the lands. However, after the instruction based on MIAIM, 66 % of students mentioned the relationship between plate boundaries and the locations of earthquakes. For example, one student wrote, “earthquake usually occurs on plate boundaries.”

More students gained knowledge about the effects of earthquakes on Earth after the instruction based on MIAIM (an average pre-test score of 13 % correct compared to a post-test score of 66 % correct in the post-test). In the pre-test, students' answers about the effects of earthquakes focused on focused on damages to houses, cars, or people. However, in the post-test, students wrote several effects of earthquakes such as liquefaction, volcanoes, tsunamis, and aftershocks.

Volcanoes. There was no significant gain in students' knowledge of the effects of volcanoes. In the pre-test, students had naïve conceptions about the effects of volcanoes on the atmosphere and weather. For example, they wrote, "it [volcanic eruption] can create pollution. it can be more polluted so harder to breathe" In the post-test, students' answers were more sophisticated. Their answers included comments such as gases or dusts which are emitted from volcano activities, and decrease of temperature by blocking sunlight. However, there was no significant change between the pre-and the post-test.

More students understood how volcanoes were characterized after the instruction based on MIAIM (an average pre-test score of 0 % correct compared to a post-test score of 40% correct). In the pre-test, most of students had no ideas about how volcanoes are characterized. However, after the instruction, more students pointed out volcanoes are categorized by 'size and shape' or 'how they are formed.'

In summary, Teresa's students gained understanding about plate tectonics after her instruction. They understood about causes of plate movement, earthquakes and plate boundaries, effects of earthquakes, and types of volcanoes more after her instruction. However, although there was improvement in students' understanding of the four topics, the percentage mean score for each topic except the effects of earthquake was not high. In particular, 60% of students still did not understand the cause of plate movement and types of volcanoes.

Dan's class

The test used in Dan's class had 10 questions about electricity. Overall, the analysis of 19 students from his class indicated that students showed an improvement in their knowledge about electricity, especially, open and close circuit, and conductor and insulator, with an average pre-test score of 38 % correct compared to a post-test score of 84 % correct(t_{18} =10.076, p <.01, σ = 2.31). In the pre-test, most students did not know what materials were needed to make a light bulb, how to connect a bulb, a battery, and wires to make a complete circuit, and why the bulb would light. However, in the post-test, most of students gained understanding of the scientific ideas. In the following paragraphs, I will explain these findings. Results on each test topic are given in table 5.6.

Table 5.6. Mean percentage correct for each test item on electricity from Dan's class (n=19)

Test Topic (Total Ten questions)	Pre-test (%)	Post-test (%)
Choose proper materials to make a light bulb (One question)	26**	95**
Draw a diagram of materials to make a light bulb (One question)	0**	89**
Explain about how the bulb light (One question)	5**	89**
Explain the role of battery in making a light bulb (One question)	47**	84**
Would a bulb in a diagram light? (Six questions)	50**	80**

**p<.01; *p<.05: These report the significance of the difference based on t-tests.

First, many more students chose the proper materials to make a light bulb in the post-test than in the pre-test (26% of students in the pre-test to 95% of students in the post test) when they were asked to chose some among several items. In the pre-test, 74% students chose insulators to make a light bulb. They circled that they needed a rubber band, plastic ruler, and thread in the pre-test. In the post-test, only 5% of students (1 of 19 students) chose those materials.

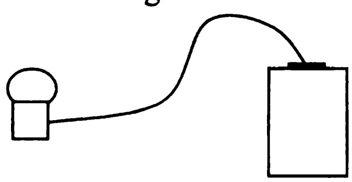
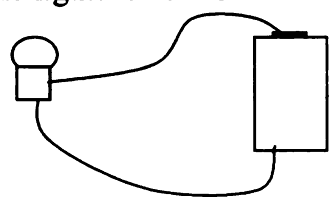
Second, more students drew a correct arrangement of the materials to make a light bulb in the post-test (0% of students in the pre-test to 90% of students in the post-test). In the pre-test, students drew the wrong pictures to make a light bulb. For example, in one drawing, a bulb was connected to only one side of a battery rather than both sides of a battery. In another example, a battery was connected only the bottom of a bulb rather than both the middle and bottom of a bulb. In other example, a bulb and a light were not connected at all. However, in the post-test, students drew the right connections between a bulb, a light, and wires.

Third, in the post-test more students wrote scientific explanations for the reason why a bulb would light. In the pre-test, they did not have any ideas or some of them wrote that because battery had energy, the bulb would light. However, in the post test, 89% of students (17 of 19 students) described that electricity or energy would flow through the wire into the bulb, or that they made right connection among a battery, a bulb, and wires. For example, one student wrote, "it will work because the battery has electricity in it. So, if you put the wires in the right place it will work"

Finally, the students' mean score on the Yes and No questions about open and closed circuits on the post-test was significantly higher than that on the pre-test. I asked whether a bulb would light or not in each of six diagrams. Figure 5.8 shows example diagrams. The analysis of the questions show that they gained their understanding of open and close circuit with an average pre test score of 50 % correct compared to an average post test score of 80 % correct after Dan's instruction (t_{18} =4.303 , p=0 < .01, σ =0.987). In addition, many students explained that a bulb in the diagram would light because it is a closed or open circuit.

Figure 5.8. Example test item about open and close circuit

For each drawing, circle YES or NO to show if you think the bulb will light or not and explain why.

1) Will the bulb light? YES NO	2) Will the bulb light? YES NO
	

In summary, Dan's students showed an improvement in their knowledge about electricity after the instruction based on MIAIM. Most of students understood what materials were needed to make a light bulb, how to connect a bulb, a battery, and wires to make a complete circuit, and why the bulb would light.

Discussion

Students from the three classes generally improved their understanding of scientific ideas on the topics when their teachers taught MIAIM-based science lessons. It is not easy to compare students' gains in their understanding of scientific ideas from each class because the science content and test from each class differed. However, when comparing gains in their understanding across the three classes with supporting evidence with classroom observations and teacher interviews, I could find some relationship between teachers' use of MIAIM and students' learning outcome.

There are some differences in student's learning outcomes from three classes. The effect size from each class was 1.52 from Richard's class, 1.32 from Teresa's class, and 2.31 from Dan's class. Most of students from Dan's class showed overall improvement in their understanding of electricity. Most students from Richard's class also showed improvement in their understanding of atoms and the periodic table. Students from Teresa's class gained understanding of plate tectonics, earthquakes, and volcanoes. However, although there was significant increase on students' understanding of the cause of plate tectonics and types of volcanoes between in the pre-and the post-tests, many students still did not understand the topics well. The average post-test score about cause of plate tectonics and types of volcanoes was low (only 40%) while the average post-test score about science topics from other classes were always more than 65%. In addition, there was no significant change in their understanding of the effects of plate movement and volcanoes. In other words, Teresa's students did not make similar gains in understanding scientific ideas compared to students' from other classes.

There are possible explanations about the differences in students' understanding of scientific ides. Again, this might be caused by the fact that her topic was difficult for students to understand than the other topics from two classes. However, Dan told that electricity is not an easy topic for students to understand, and his class included both 3rd and 4th grade students while the electricity was content area for 4th graders. He used many aspects of MIAIM to help students to understand scientific ideas about electricity. Compared to him, after the pre-test from Teresa's class, she said that she was surprised at the test result showing that students did not know the cause of plate movement. She put her efforts to help students understand it. However, she used didactic approach when teaching plate movement and the teaching approach did not seem to be effective in helping students understand scientific knowledge about the topics. The differences among the three classes seemed to show the relationship between teaching approach and students' understating of science ideas. While MIAIM-based lessons were effective in helping students to learn electricity from Dan's class, lessons loosely based on MIAIM were not as effective in helping students to learn plate movement from Teresa's class.

Chapter Six: Conclusion

Summary of findings and discussion

In this section, I summarize the findings and discussions in this dissertation. After summarizing and discussing changes in the teachers' approaches and practices, I will summarize and discuss students' changes.

Summary and discussion about findings related to teachers

Findings. Analysis of the data indicates that after the teachers participated in professional development activities about MIAIM, there was a modest change in teachers' teaching approaches thought teachers used several features of MIAIM in their science lessons. Regarding teaching approaches, before the intervention, Richard used a combination of didactic and hands-on approaches for teaching science. It appeared that he was using laboratory activities for reinforcing scientific ideas rather than helping students participate in scientific inquiry practices. During intervention, I suggested that Richard help students to find patterns in elements in the periodic table as well as I explained MIAIM. After the intervention, Richard incorporated some features of MIAIM. He taught the periodic table with an inquiry approach and had students find patterns in data. The sequence of activities about the periodic table met all steps of MIAIM. When teaching other topics, he used a combination of didactic and hands-on approaches but he constantly established a central question for hands-on investigations, and applied scientific explanations to new situations.

Another teacher, Teresa, used a combination of didactic and inquiry approaches before the intervention, In some lessons, she lectured on scientific information, but in other lessons, she gave her students opportunities to develop explanations using data. During intervention with Teresa, I explained MIAIM and, after meeting for professional development, I sometimes asked to use some practices of MIAIM. After the intervention, Teresa's teaching approach did not change substantially. She used a didactic approach to teach plate tectonics. In other classes, she used an inquiry approach and her lessons fit all steps of MIAIM. She consistently posted central questions for investigations, asked students to find patterns in data, and used many application activities.

The third teacher, Dan, used an inquiry approach for teaching science before the intervention. He tended to present science in his class "as scientists do" their research. Although he tried to help students both understand scientific explanations and participate in scientific practices, his lessons did not include many features of inquiry lessons. During intervention with Dan, I explained MIAIM and commented some of his worksheets used in previous years. After the intervention, Dan used an inquiry approach for teaching science and used many aspects of MIAIM in his inquiry lessons. He consistently established central question for investigations, helped students find patterns in data, and asked students to apply scientific ideas to new situations.

Regarding specific instructional practices, after the intervention, teachers commonly used three instructional practices listed in the MIAIM that they did not frequently use before the intervention. First of all, the three teachers tended to consistently pose central questions for investigation at the beginning of class activities. In particular, after the intervention, Dan and Richard more clearly and more consistently established a central question. Teresa consistently posed central questions for investigation before and after the intervention. In addition, the three teachers focused on making patterns explicit more after the intervention than before the intervention. They asked students to find patterns by themselves rather than they explained the pattern. In addition, during the post-interviews, Dan and Richard expressed the importance or benefits of making patterns explicit in science or science teaching. Finally, the teachers focused more on helping students apply scientific knowledge to new situations after the interventions than they did before the intervention. In addition, the application activities related more to real-world situations.

However, there was no substantial change in teachers' use of two instructional practices. For example, after the intervention, teacher provided experiences that are appropriate for learning goals, as teachers did before the intervention. Richards and Dan continued to provide experiences with phenomena after the intervention. Teresa provided second-hand data for helping students understand volcanoes and earthquakes. In addition, teachers provided explanations through a lecture format or students' book reading but they still did not explicitly give students chances to compare and revise their ideas with scientific ones after the intervention.

Regarding motivational practices, after the intervention, the teachers put more effort towards making science relevant and interesting to students than they did before the intervention. For example, the teachers explicitly related science to students' everyday lives, especially at the beginning and end of their units after the intervention. Before the intervention, Dan and Richard tended to explain the importance of learning science from a scientist's perspective or for students' future jobs. However, after the intervention, they discussed the relevance of the topics to students' everyday lives and gave several real-world examples. Teresa also more frequently tried to relate science to students' lives after the intervention. In addition, Dan and Richard used a different kind of practices to catch and hold students' interest after the intervention. Before the intervention, they made some effort to making science interesting, mostly through providing opportunities to engage in hands-on activities or by using games, simulations, humor or other fun features. After the intervention, in addition to doing these things, they modified the design of their learning activities to include features that would enhance the appeal of the activities. Specifically, they told interesting stories related to the topics students would learn about and allowed students to project themselves into situations. By using the stories, the teachers established questions for following inquiry activities or projects.

There was no substantial change in teachers' use of two motivational practices. Regarding the practice of supporting student's autonomy, teachers increasingly used practices in two classes after the intervention, but they also used other practices that might undermine student's autonomy. Regarding practices of knowing students and using knowledge about students, after the intervention, teachers continued to assess students' prior knowledge. They also tried to relate science to students' everyday lives and there were a couple instances that teachers considered students interests when designing and enacting their lessons. However, I did not notice any substantial change in how they used knowledge about their students to enhance students' valuing of learning science.

Discussion. There are important points resulting from the findings about the teachers' changes in teaching practices after the intervention. First, the results show that MIAIM can be used as a tool to help teachers use teaching practices for scientific inquiry, application, and motivation. In chapter two about literature review of this study, I introduced a model of teacher learning useful for understanding outcome of this study. In the model showed components of teacher learning over three different time intervals. At time 1, teachers interpret new knowledge and practices through their existing knowledge and practices and learn new ideas and skills by participating in professional development (PD) activities. The PD activities influence what teachers learn, but what teachers already know and do influences the interaction with teacher educators during the PD activities. In this study, during the PD activities using MIAIM, I tried to help teachers synthesize ideas about reform-based science instruction and value aspects of motivation by discussing important components of inquiry, application, and motivation described in the model. I also commented teachers' curriculum materials or activities. Teachers might interpret MIAIM and my comments based on their existing knowledge and practices.

At Time 2, teachers enact the curriculum materials or class activities talked about during PD activities. In this study, teachers practiced planning and teaching science lessons that fit the intent of MIAIM. They established central questions for investigation, and provided experiences with phenomena, helped students to find patterns in data by themselves. They also explicitly related science to students' everyday lives and some of them used stories to make contexts for scientific investigations. Two of the three teachers said that they would continue to use some MIAIM practices. For example, Richard expressed that he would use similar lesson plans to teach the periodic table focusing on finding patterns in elements in the next year. Dan also expressed that this year's worksheet format was more scientific that those of his previous years' worksheet and would use them later. In other words, teachers incorporated some aspects of MIAIM in their science lessons.

At time 3, teachers transfer their new knowledge and practices to teach different curriculum materials. The application of the knowledge and practices is also influenced by the features of the curriculum materials, their students, and other contexts. In this study, when I phased out my support and teachers taught different topics and lessons, they still used some of MIAIM practices. For example, when Richard taught other topics, he used a combination of didactic and hands-on approaches but he constantly established a central question for hands-on investigations, helped students apply scientific explanations to new situations and related science to students' everyday lives. Teresa enacted inquiry lessons that fit the steps of MIAIM. Finally, Dan designed a new worksheet when teaching about motor, and the lesson fit the first three steps of MIAIM. These result shows that teachers had been learning to teach science lessons fit the intent of MIAIM whose goals are to help students participate in scientific practices and enhance students' valuing of learning science.

Second, the amount and kinds of changes in the teachers' teaching practices seemed to depend on several factors: teachers' initial teaching approaches and practices, experiences with using MIAIM in their class, features of the scientific topics, and school contexts. First of all, teachers' initial teaching approach and practices influenced their use of MIAIM. In this study, depending on their initial teaching approach and practices, the teachers embraced either many or some aspects of MIAIM. Of the three teachers, Dan's initial teaching approach and goals in teaching science were most similar to the goals of

MIAIM, and after the intervention, he used many aspects of MIAIM more consistently than the other two teachers. Just as children's learning occurs within the 'zone of proximal development' (Vygotsky, 1978), teachers seemed to have their zone of proximal development in their learning to use MIAIM to teach science. Knowledge and practices presented by MIAIM is domain specific. Some teachers, who have similar goals and approaches to those of reform-based science teaching and want to help students appreciate their learning, may use MIAIM to design class activities more frequently than others. Steps and descriptions in MIAIM may give them guidelines for accomplishing their goals for teaching science. However, teachers whose goals for teaching science are somewhat different from those of MIAIM may not see the affordances of using MIAIM and not frequently refer to it when planning and teaching.

In addition, teachers' experiences with using some features of MIAIM in class might have influenced their judgment of the utility of MIAIM and their next trial of the practices. There is some evidence supporting this theory from teacher interviews and class observations. In this study, when students reacted positively to the teachers' new instructional and motivational practices in terms of their participation in class activities or understanding of scientific ideas, teachers tended to judge that new practices were useful in their teaching and they used or wanted to use these practices later. The relationship between students' responses during instruction and teacher learning is also supported by other researchers saying that teachers intuitively look to their students for feedback about the instruction and that student performance influences what teachers learn (Fishman, Marx, Best, & Tal 2003; Richardson, 1996).

The features of the science content area might also have influenced teacher's use of MIAIM. The features of the content area seemed to include the amount of or difficulty in scientific explanations that students have to understand, availability of hands-on activities for students to participate in, or easiness in relating science to students' lives. It seemed to be easier for teachers to make inquiry lessons and relate science to students' lives in some contexts than other contexts.

Finally, school and classroom contexts including features of students seemed to influence teachers' use of MIAIM. In the study, Teresa showed less change in her using of MIAIM practices than the other two teachers. When this study was conducted, Teresa's school was less stable and she had less time to teach science compared to the other two teachers. In this context, it may not have been easy for her to try new teaching practices. In addition, her students seemed to differ from the other two teachers' students in terms of their level of poverty, academic scores, stable school environment and so on. These different features of students might have influenced interactions among the students and between the students and their teachers, and may have influenced the teachers' judgment of the utility of MIAIM practice

Summary and discussion about findings related to students

Findings. Analysis of data shows several important results about student's valuing of learning science, their levels of participation in class activities, and understanding of scientific ideas after students learn science after MIAIM based instructions.

First, there were some positive changes in students' valuing of learning science from all three classes. In Richard's class, there was a moderate change in students' understanding of the relevance of science to students' lives after his MIAIM based lessons. His students became more appreciative of how science is related to their lives. In Teresa's class, there was a small increase in students' interests in science. Five of 10 students reported that they were more interested in science or science class. Finally, Dan's students showed the biggest change among the three classes' students. After Dan taught electricity based on MIAIM, 66% of students reported that they were more interested in science and understand why learning electricity is important or relevant to them. From the three classes, some students attributed their change in their valuing of learning science to their teacher's teaching practices, such as using hands-on activities or labs, their learning of new topics such as electricity, or their understanding of the relevance of science to their lives. However, from all classes, there was no change in their understanding of how science is useful for their future jobs. In addition, the analysis of Likert scale items did not show any significant change in students' general and situational interests in science although some of students from each class reported, in their answers to open-ended questions, that they were more interested in science.

There was also change in the students' level of participation in class activities from two classes. Students from Richard's and Dan's classes participated more in class activities when their teachers taught science lessons based on MIAIM. However, there was no change in students' level of participation in Teresa's class. In addition, from three classes, there was no significant change in students' perceived efforts to learn science between the pre- and post-surveys.

Finally, students from the three classes generally improved their understanding of scientific ideas on the topics when their teachers taught science lessons based on MIAIM. However, there was also a difference in students' gains among the three classes.

Most of students from Dan's class showed overall improvement in their understanding of electricity. Most students from Richard's class also showed improvement in their understanding of atoms and of The Periodic Table. Students from Teresa's class gained understanding of plate tectonics, earthquakes, and volcanoes. However, although there was a significant increase on the students' understanding of the cause of plate tectonics and the types of volcanoes between the pre-and the post-tests, more than half of the students still did not understand the topics well.

Discussion. The lessons based on MIAIM seemed to have positive influence on students' valuing of learning science, their participation in class activities, and their understanding of scientific ideas. First, science lessons based on MIAIM are effective in motivating some students to learn science. In this study, there was some increase in students' understanding of how science is useful or important to their everyday lives, and students' interest in science. The changes seemed to be closely associated with what kinds of practices of MIAIM teachers used and how frequently they used the practices. The patterns in the teachers' uses of practices and their students' changes support this pattern. For example, in this study, Dan and Richard put their efforts into relating science to student lives more than Teresa did. The two teachers gave concrete examples to show how atoms or electricity is related to students' everyday lives. They also gave students opportunities to think about the relevance of science to their everyday lives. Although Teresa had class discussions about how volcanoes and earthquakes are important to their lives, she did not give students concrete examples or opportunities to think about the relevance of the topics to their lives. As there were differences in how teachers related science to students' lives, students from Dan and Richard's class reported that they understood that science is relevant or important to their lives more than Teresa's students did. In addition, students whose teachers used several inquiry lessons using hands-on activities tended to be more interested in science. Of the three classes, Dan used the most hands-on activities more than the other two teachers and his students reported that they are more interested in learning science.

Second, changes in teachers' instructional and motivational practices influenced students' level of participation in class activities. In this study, students from Dan's and Richard's classes participated in their class activities during the lessons based on MIAIM more than they did before. There are two explanations for this change. First, students participated in the lesson more actively than before because the lessons based on MIAIM were more interesting or understandable to them. Teachers' use of instructional practices addressing central questions for investigation or having students find patterns by themselves may help students understand the purpose of the lessons or make the lessons interesting. Second, because students gained their understanding of how electricity or atoms are relevant to their lives though their teachers' messages in class, their motivation to learn science increased, and therefore, they participated in the activities during science class.

However, results from the survey did not show any changes in students' perceived effort in science classes between before and after their teachers' participation in the intervention for teacher development. There is one possible explanations for the result. The Likert scale items, measurement on students' perceived efforts to participate in class activity, may not have been good enough to measure students' behavioral efforts to participate in class activities. Even though students participated more in class activities, students did not perceive those changes.

Finally, science lessons based on MIAIM are effective for helping most students understand scientific ideas. In this study, students from the three classes generally improved their understanding of scientific ideas on the topics when their teachers taught science lessons based on MIAIM. While lessons based on MIAIM were effective in helping students to learn electricity in Dan's class, lessons loosely based on MIAIM were not effective in helping students to learn plate tectonics in Teresa's class.

Implication of the study

It is essential to help teachers learn to teach science in a way that supports students' scientific practices and their valuing of learning science. When teachers teach science in class, such knowledge and practices will enable them to sequence class activities and interact with students effectively support to student learning and motivation. This study has focused on the use of a motivation-based inquiry and application instructional model as a tool to scaffold development of instructional and motivational practices in elementary and secondary science teachers. Although the sample size of this study was small (three teachers and their classrooms), this study showed that teachers can help students participate in scientific practices, learn important ideas, and value learning science with the help of MIAIM as a conceptual tool and contextualized support from professional development activities and curriculum materials such as worksheets and lesson plans. This study is meaningful because it shows that teachers can use some instructional and motivational strategies to support students' scientific practices and their valuing of science in their science classes. With the support from MIAIM, PD activities, and curriculum materials, teachers can easily use some practices such as helping finding patterns in data or making the relevance of the topics explicit to students.

However, individual teacher development differs depending on the teacher's current teaching approach and practices, experiences with using the tool (MIAIM) in class, science content, and school contexts. Therefore, while instructional models such as MIAIM can provide a 'structure' of a science lesson, professional development facilitators should leverage a teacher's existing views and practices, and support the teacher in having success in using the tool in their classes. For this, it is important to have cooperation between the PD facilitators and teachers. Then, teachers may find the benefits of using the tool in supporting their teaching and develop their teaching practices.

Finally, this study provides the empirical evidence for the influence of teacher development on students' motivation and learning. Changes in teacher practices influence students' valuing of science and their learning. Teachers' messages and practices related to how science is important, relevant, or interesting to students influences how students think about science and their level of participation in class activities. Not only improving teacher's instructional practices, but also developing teacher's motivational practices, is important in order to enhance students' valuing of learning science and to learn science.

Limitations and Directions for Future Research

While this study shows the influences of professional development activities around a motivation based instructional model on teacher development and student's learning, and shows the possibility of using motivational and instructional practices to support students' scientific practices and their valuing of learning science, there are several important limitations to this work. These limitations involve understanding contexts that may influence teacher development, lack of control groups to compare the influence of teacher development on students, a short period of professional development intervention, and a small number of participants.

Understanding contexts that may influence teacher development

While this study focuses on the teaching approaches and practices of individual teachers, it focuses less on their school or classroom contexts or communities that may influence teachers' use of MIAIM and their development. Because learning is situated in contexts, teachers' use or each of use of some aspects of MIAIM may be influenced by other factors such as classroom situations, cultural norms of the students in her school, school policies, or available curriculum materials. In particular, in this study, it was hard for me to collect data in Teresa's class, an urban middle-school science classroom. For example, although I eventually had meetings with her to introduce the model and support her use of the model, she was very busy due to her administrative work and a school-wide schedule change during a semester, and due to the school's request of doing something not related to teaching science in her class. In addition, I could not get any parental permission for this study from one class at first and had to change the classroom that I observed. Although these are specific examples, it shows that her school contexts and features of students are different from features of schools and students from the other two teachers. Therefore, her use of MIAIM less frequently may be related to other contexts as well as her own teaching approach or practices to leverage for her students in an urban school. There should be research on considering contexts that might influence a teacher's use of MIAIM and their development.

Lack of control groups to compare the influence of teacher development on students

Another limitation of this study is the lack of comparison classes that could show the influence of teacher development on students' motivation and learning. This study provides evidence for the influence of teacher development on students' changes in their motivation and understanding by comparing the relationships between patterns in teachers' use of MIAIM and changes in their students' motivation and understanding. Because after the intervention Teresa showed less changes in her use of MIAIM than the other two teachers, I was able to find some relationships between teacher practices and students' outcomes. However, students' changes in their motivation or understanding may also be influenced by the features of science contents that they learn as well as by the teacher's use of specific motivational or instructional practices. Therefore, if there was a comparison class where a teacher taught on the same topic, but did not participate in the professional development activities, it may provide stronger evidence for the relationship between teacher development and students' learning and motivation.

Short period of professional development intervention

Two weeks of intervention and interaction throughout the units was a brief time for introducing and supporting all the features of MIAIM and help the teachers incorporate MIAIM into their specific lessons. Although I introduced big ideas of MIAIM, such as the sequence of MIAIM and motivational principles, I was not able to provide enough examples for all motivational and instructional practices. Therefore, I had to focus on a few practices that seemed to be important to individual teachers. Patterns in changes in teacher practices may show the accessibility of some practices of MIAIM to their classroom. However, they may also be related to the focus of discussions with teachers during the intervention. Therefore, there should be continuous effort to develop ways to introduce MIAIM to teachers effectively, and there is need for research as to why teachers use specific practices but not other practices and how to support teachers using other practices.

A small number of participants

In this study, I designed and used MIAIM to support teachers' teaching practices and examine the influence of professional development on students. Although this study shows several positive influences of professional development activities using MIAIM on teachers and students, the sample size of this study was small (three teachers and their students) and the three teachers were not necessarily representative of teachers as a whole. Two of the three teachers were 8th grade teachers and the other was 4th grade elementary teachers. There are many different teachers in the world who teach different grade levels and science content areas, work at different schools, and have different teaching orientations and practices. In addition, only 52% of students (16 of 31 students) from Teresa's class participated in the study to provide data for the effects of the professional development on student's learning and motivation although 72% of Richard's students (18 of 25 students) and 91% of Dan's students (21 of 23 students) participated in this study. Therefore, it was not easy to generalize the results for all teachers and students.

However, it demonstrated the potential of using instructional models for teacher development and students' learning. Therefore, there should be more research with many teachers and their students in order to understand how to support teacher learning with instructional models such as MIAIM and what effects teacher development have on students.

Conclusion

Teachers have difficulty helping students participate in scientific practices and they do not frequently communicate why learning science is worthwhile. However, it is important to enhance students' valuing of learning science, learn scientific ideas, and participate in scientific practices. This study shows that a motivation-based instructional approach along with the accompanying model such as MIAIM can be useful for scaffolding the development of instructional and motivational practices in elementary and secondary science teachers. In addition, it explains that teachers' use of the approach/tool is influenced by several factors including their current teaching approach and practices, their experiences with using the model in the class, features of science contents and school contexts. It also provides the empirical evidence for the influence of the teacher development on students' motivation and learning, and suggests a new teaching approach based on both current motivational research and teacher learning. In particular, it advances the knowledge about value aspects of motivation, especially in the field of science because there has not been much research on value aspects of motivation theories in elementary and secondary science learning. In the future, more research is needed about the effects of professional development experiences surrounding instructional models such as MIAIM on various teachers and students, that consider the features of schools and classroom contexts in order to develop knowledge about teachers' learning and the effects of teacher development on student learning and motivation. Such efforts will improve science education by helping teachers effectively use instructional and motivation practices to help students become scientifically literate citizen who participate productively in scientific practices and value their learning of science.

Appendix 1. Teacher actions/strategies for instruction in MIAIM

Model Stage	Activity Functions for instruction	Teacher Actions/ Strategies
Engage	Establish a Problem/ Ask a Question	• Pique students' curiosity by creating new experiences or drawing on prior experiences to pose a problem. • Provide a problem/question that is comprehensible, relevant, and motivating to students.
	Elicit Student Ideas	• Engage students in hypothesizing about patterns in their experiences • Probe students' understanding • Invite students to raise questions & think about their own ideas
Explore & Investigate	Explore Phenomena	• Create opportunities for students to mess around with materials & ideas (experiences) • Create opportunities for students to try out & test ideas (hypotheses) • Create opportunities for students to collect and analyze data/evidence (look for patterns)
	Explore Student Ideas	• Provide opportunities for students to share their ideas. • Have students share ideas about patterns and evidence for them • Have students comparing/coming to agreement about observed patterns.
Explain	Students explain patterns	• Provide opportunities for students to share their ideas. • Have students share their own explanations (reasons) for patterns. • Have students share ideas of how their explanations answer the question.
	Introduce Scientific Ideas	• Represent scientific ideas accurately and comprehensibly • Continue to build congruence between student thinking and scientific ideas
	Compare Student Ideas	• Provide opportunities for students to share & compare ideas with each other • Use formative assessments to make adjustments to teaching and to compare student ideas to scientific ideas
Apply	Practice with support	• Provide opportunities for students to apply the scientific explanation in new contexts

	Practice with fading support	• Provide opportunities for students to apply the scientific explanation in new contexts with diminishing support from the teacher.

Appendix 2. Example Lesson Plan about the periodic table

Learning goal: Understand that elements in a group in the periodic table (families) have similar physical and chemical properties due to the same outer electron structures of atoms

Model Stage	Description	Activity Functions for instruction	Activity Function for motivation
Engage	A teacher asks a question about why some people look similar or different. (e.g., man vs. woman, Asian vs. American) He asks a question of how students/their parents classify clothes or CDs. He asks a question of what makes up a car and why Michigan is famous for car industry.[11]		Understand the relevance of the topic to students' lives (Use an analogy familiar to my students)
	A teacher shows gold, silver, calcium, copper, iron, neon, carbon, mercury, and oxygen. He asks about students' experiences related to the elements. He asks about the properties of them. He says that as people look similar or different, so do chemical elements. He asks about why some elements have similar or different properties. He explains the benefits of learning the content to our society (e.g., We use some elements for a certain purpose. all metals are good conductors of electric current. The electrical wires used in your home are made of copper. Most metals are good conductors of thermal energy. However, nonmetals such as oxygen are poor conductors.)	Ask a question	Understand the relevance of the topic to students' lives (Explain the relevance/benefits of learning of the contents to society.)
	Students talk about their ideas about the question.	Elicit students' ideas.	
Explore & Investigate	Students find out properties of their own elements. (Students will have opportunities to choose which elements they will focus on.) The teacher will give students materials made of the elements, and a	Explore phenomena	Autonomy-support (Providing choices) Hold attention

[11] A teacher may ask all of three questions or choose one of them.

	picture of structures of atoms of the elements. Groups of four students find out common patterns of four elements.		and interest (Providing opportunities to engage in hands-on activity, Use authentic materials)
	They share their ideas of why the elements have common patterns.	Explore student ideas	
Explain	Students in each group explain the common patterns of the elements in each group They share their ideas about why elements in a group have common patterns.	Students explain patterns.	
	A teacher explains that elements in a group in the periodic table (families) have similar physical and chemical properties due to the same outer electron structures of atoms.	Introduce scientific ideas	
	Students compare the given scientific explanation to their own ideas.	Compare students' ideas	
Apply	A teacher explains that hundreds of years ago, some people often spent their whole lives trying to find a way to make gold. He asks whether and how students can make gold from other metals, such as lead. Students discuss their ideas in groups and share their ideas in a whole group discussion.	Practice	Understand the relevance of the topic to students' lives

Appendix 3. Motivational principles in MIAIM

Motivational principles	Description	Related theory
Relevance	Students are more willing to engage with content that they view as relevant to their agendas and applicable to their lives outside of school.	Interest theory, Neo-Dewyean work, Classroom observation studies
Autonomy-supportive	The more students perceive a learning activity as autonomous rather than extrinsically controlled, the more they experience intrinsic motivation. Students can perceive a learning activity as autonomous or self-determined by adopting values of the task as personally important or integrating the values into their coherent sense of selves.	Self-determination theory
Situational interest	You may catch and hold students' situational interest through designing learning activities that students are likely to find enjoyable or incorporating elements of fantasy, humor, novelty, and variety into class work. Students' sustained situational interest can develop into personal interests in science.	Interest theory, Intrinsic motivation theories
Knowing my students & Using knowledge about students	Knowing about students' experiences can help you link your students' ideas with those in the content area and become more invested in knowing the outcome. Knowing about students' interests or values can help you link their interests or values with those of science.	Expectancy*value theory, interest theory, intrinsic motivation

Appendix 4. Teacher actions/strategies for motivation in MIAIM

<table>
<tr><th>Model Stage</th><th>Activity Functions for motivation</th><th>Teacher action/Strategies</th></tr>
<tr><td rowspan="2">Engage</td><td>Understand the relevance of the topic to students' lives</td><td>Explain the relevance/benefits of learning of the content to students, schools, society
State how the learning would build on my students' existing skills
Use analogies familiar to my students from past experience
Attempt to link content to student needs such as the need for affiliation, power, and achievement,
Point out its current or future applicability in students' lives
Show enthusiasm for its applications
Ask students to determine for themselves why or how the content is relevant to them</td></tr>
<tr><td>Catch students' situational interests</td><td>Relate topics to my students' interests
Use themes relating to topics widely viewed as interesting (animal or human life, injury or death, sex, scandal, and so on)
Allow students to project themselves into situations, such as identifying with a central character in a story
Include features that will enhance the activities' appeal (fantasy, novelty)
Provide opportunities to observe models who display competence in science
Use oral or written presentations organized within a narrative format
Use games, simulations, humor, or other fun features</td></tr>
<tr><td>Explore & Investigate Explain</td><td>Support students' autonomy</td><td>Provide choices
Minimize extrinsic performance pressures
Refrain from the use of contingencies to motivate behavior
Encourage students to solve problems in their own ways rather than insisting on a single method
Invite students to ask questions and suggest ideas for individual learning projects
Provide timely positive feedback</td></tr>
</table>

	Hold students' attention and interest	• Provide opportunities to engage in hands-on activity • Use authentic material and activities • Create recognition of the discrepancy between what we think is true and what the situation implies. • Provide an appropriate level of challenge and support
Apply	Understand the role of science	• Model applying new ideas to everyday life • Have students apply new ideas to their everyday lives or their community • Give students opportunities to become aware of their progress and mastery • Help students realize the good feelings they experienced during the class and attribute these feelings to their involvement in science lessons • Have students talk about benefits, affordances of learning science

Appendix 5. Interview Protocol about teachers' teaching approaches and practices

1. Pre-intervention interview questions

1) Questions about background information

Information about students:

Total Students:
Number of Males/Females:
Ethnicity of class:
Economic status of students

Information about teacher

How many years have you taught in total?
- At the elementary level?
- At the middle school level?
- At the high school level?
- Other?

Certifications?

What degree(s) do you hold? (both science and/or education)
- Bachelors?
- Masters?
- Specialist?
- Other?

Information about teaching schedule

How do you teach this year?

Which topic do you think appropriate for doing inquiry lessons or incorporating motivational strategies for this study?

Other background information:

2) General questions about the teacher's teaching approaches and practices of instructional and motivation

1. What is your goal in teaching science?
2. What is the general sequence of activities in your lessons?
3. How did you teach (the name of unit that teachers would incorporate MIAIM after the intervention) in previous years?
4. How do you define 'inquiry'? What do you do to promote science inquiry or application with your students?

Give examples.

a. What kinds of driving questions do you pose?
b. What kinds of experiences do you provide?
c. How do you help students to find patterns in those experiences?
d. How do you link those patterns with explanations?
e. How do you help students apply these explanations to other contexts?

5. Why do you think that learning science is worthwhile?
6. What do you do to motivate your students to learn science? Give a specific example of how you have done this in the last week.

7. How do you find out your student's prior knowledge, interests, or values? How do you relate those to modifying units/sequences or the content of the unit?
8. When you notice that your students don't value science, what do you feel you need to do as the teacher?
9. What other things do you think I should ask about your science teaching? What things seem important to you?

3) General questions about the enactment of specific science lessons

1. What goals do you have for what you want students to learn about science in the lesson?
2. Why did you say or do this when you taught the lesson? What reasons did you have for making this decision?

2. Post-intervention interview questions

1) General questions about teachers' teaching approaches and practices of instructional and motivation

1. What is your goal in teaching science? Do you think that your goal in teaching science has changed during the last two or three months?
2. How do you define 'inquiry'? What do you do to promote science inquiry or application with your students?

Give examples.

a. What kinds of driving questions do you pose?
b. What kinds of experiences do you provide?
c. How do you help students to find patterns in those experiences?
d. How do you link those patterns with explanations?
e. How do you help students apply these explanations to other contexts?

3. What do you do to motivate your students to learn science? Give a specific example of how you have done this in the last week.

2) General questions about enactment of specific science lessons

1. What goals do you have for what you want students to learn about science in the lesson?
2. Why did you say or do this when you taught the lesson? What reasons did you have for making this decision?

3) Teacher views on the impact of professional development

1. We worked together to think about how the lesson sequence or motivational principles in MIAIM could work in your unit. I want to revise MIAIM to help pre-service teachers learn about instructional and motivational practices in their science methods courses. Could you give advice about what aspects of MIAIM need improvement or have been helpful? Is there anything unclear in the model that made you difficult to interpret?
2. Could you explain how you used MIAIM in your lessons? (I showed a document of MIAIM and asked questions about how they used each

sequence of MIAIM in their lessons)

3. Is there anything that you want to talk about MIAIM or your experiences related to it?

Appendix 6. A survey to assess students' motivation to learn science

1. Likert-scale questions

All of personal interest items will be put together as one group of items at the beginning of the survey. These items will prefaced with the statement: "For the first 4 questions, think about how you felt about science before the schol year began."

All of the other items will be randomly mixed in the rest of the survey.

All of the items will have the following response format.

Our class is fun

Strongly agree agree slightly agree neutral slightly disagree disagree stronly disagree

Personal interest (Interest value in science from a personal perspective)

1. In general, I find working on science assignments boring.
2. I like doing science.(e.g., reading magazines or books about science, or doing experiments)
3. I'm interested in science.
4. Compared to other subjects, science is exciting to me.

Job related utility value

5. Learning science is useful for what I want to do after I graduate and go to work.

Everyday related utility value

6. What I learn in science class is useful for my life outside school.
7. The stuff I learn in this class will never be used in real life.

Situational interest (Interest value in science class from a situational perspective)

8. Our science class is fun.
9. I actually look forward to going to science class this year.
10. Our science class is dull.
11. This year I like science.
12. I don't find anything interesting about science this year.

Importance

13. I see the science I learn as important.
14. I feel that working hard in science class is important.

Perceived efforts

15. I put forth my effort during the science lessons.
16. I work hard to learn about science.

2. Open-ended questions

1. Do you think science is useful? What parts of science are useful to you? Why? What parts of science are not useful to you? or why not?
2. Do you think science is interesting? What parts of science are interesting to you? Why? What parts of science are not interesting to you?

3. Do you think science is important? What parts of science are important? Why? What parts of science are not? Why not?
4. How is the topic that you will learn (or learned) related to your everyday life? Give several examples of how you applied big ideas of the topic to your life.
5. (Only in the post-survey)Think about what you felt toward science about two month ago. Do you think that your perception or attitude toward science has changed after this unit of instruction? If yes, how have they changed? Why? If not, what your perceptions and attitudes are? Why do you think they don't change?

Appendix 7. Interview protocol about students' motivation

1. Pre-intervention Interview questions
    1) What subjects do you like best? Why?
    2) What do you want to be in the future? What is your dream?
    3) Tell me more about what you think about science.
    4) Do you like science? What parts of science do you like? why? What parts of science do you not like? Why not?
    5) Do you think science is useful for your everyday life or your personal goals? What parts of science are useful? Why? What parts of science are not useful? Why not?
    6) You will learn <u>(the name of unit)</u>. What do you want to know about it? How will the topic that you will learn be related to your life out of school or help you to be a better person?
    7) I know one student from Korea. She does not like to learn science and do not want to study science in school. Do you have any suggestions for me to help her to study science in school?

2. Post-intervention Interview questions
    1) Of the stuff that you learned in the instruction of (the name of unit), please tell me anything that you remember. Do you have anything that was interesting to you? Why?
    2) What parts of the stuffs are important to you? Why? What parts are not important? Why not?
    3) Which parts of it are useful to you? Why? Which parts are not useful? Why not?
    4) Do you think that your attitudes toward science or science class have been changed when you learn about the unit? If yes, how and why?
    5) Has this science class during the unit been similar to or different from other science classes you have had in the past? (For example, are there any differences in you learning about land forms and electricity[12]? If so, how?)
    6) What teacher talks or actions do you think will be helpful for other students to be more engaged in learning science?
    7) I know one student from Korea. She does not like to learn science and do not want to study science in school. Do you have any suggestions for me to help her to study science in school?

---

[12] I asked this question to Dan's students. Dan taught about land forms before the intervention and electricity after the intervention.

Appendix 8. Test to assess students' understanding of scientific ideas from Richard's class

Definition of atom

1. The smallest particle into which an element can be divided and still be the same substance is called

A. nucleus

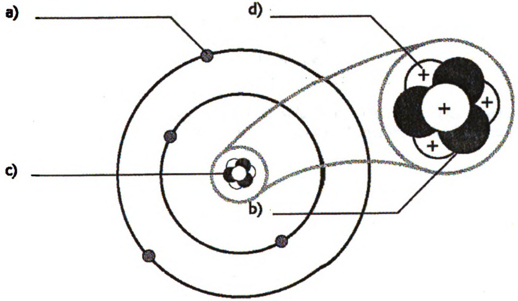
C. atom

B. electron

D. neutron

Structure of Atom

Use the diagram below to answer the flowing four questions



2. Which letter refers to the negatively charged particles?
3. Which letter refers to the positively charged particles?
4. Which letter refers to the particles with no charge?
5. Which letter refers to the dense center of the atom?

Atom drawing

6. Use the periodic table to answer to draw an atom of the element. Draw the atom with the atomic number 11.

Feature of the periodic table

7. In the modern periodic table, the elements are arranged in order of

A. Atomic mass C. Atomic number

B. Chemical Symbol D. Number of Neutrons

8. The number of the periodic table tells you

A. how many electrons there are in the atom   C. the number of proton
B. The atomic mass   D. How many electron energy levels in the atom

Interpretation of the periodic table.
Use the figure below to answer the following questions.

Blue													Green		Yellow		
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	kr

9. Which of these elements is the least metallic?
   A. V   C. Co
   B. Zn   D. Se

10. Which element group has all nonmetals?
   A. K, Ca, Sc   C. V, Cr, Mn
   B. Se, Br, Kr   D. As, Se, Br

Essay Question
11. Think about how you felt about the periodic table about a month ago. Describe how your perception or attitude of the periodic table has changed after this unit of instruction.

Appendix 9. Test to assess students' understanding of scientific ideas from Teresa's class

Cause of plate movement

1. It is very interesting to see the Continents fit together. Your friend, Bill, tried to fit together copies of the continents of a world map into one large landmass like the below picture. He heard that long ago one scientist argued that the continents had once been joined to form a single super continent. Currently, some scientists say that some parts of the earth are broken into several huge pieces, called plates, and those pieces move slowly. Your friend was curious about what makes those pieces including continents move. So, he asked the question of what makes them move. What is your explanation?

Effect of plate movement

2. What are effects of plate movement on earth and our lives?

Earthquakes and plate boundary

3. Are some places more likely to experience an earthquake than others? Explain your answer

Effects of Earthquakes

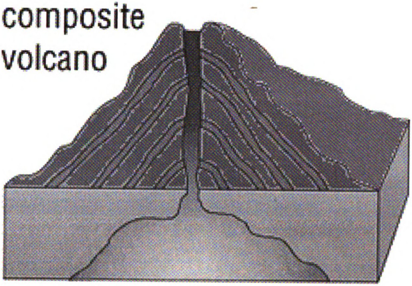
4. What are the major hazards produced by earthquakes?

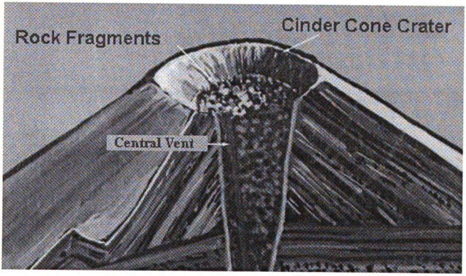
Effects of Volcanoes

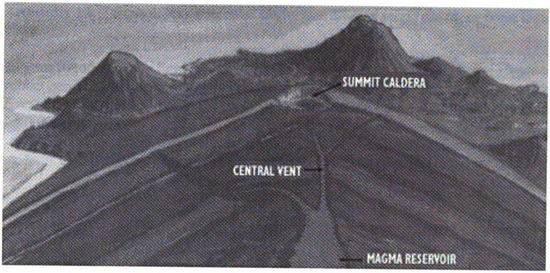
5. How can explosive volcanic eruptions affect the atmosphere and weather around the world?

Types of Volcanoes

6. How are volcanoes characterized? (Use the pictures to guess)


composite
volcano


Rock Fragments
Cinder Cone Crater
Central Vent

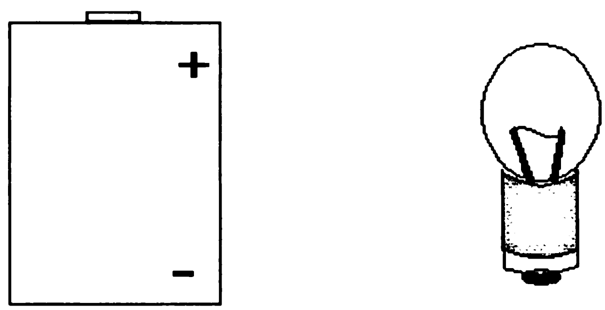

SUMMIT CALDERA
CENTRAL VENT
MAGMA RESERVOIR

Appendix 10. Test to assess students' understanding of scientific ideas from Dan's class

1. Your friend wants to light the bulb. She has one flashlight bulb, one battery, two rubber bands, two plastic rulers, two pieces of thread, and two wires. However, she does not know how to light the bulb. Could you use some of the materials and help her to light the bulb?

1) What materials will you use? Draw a circle on the materials that you will use.
   One bulb, one battery, one rubber band, two rubber bands,
   one plastic ruler, two plastic rulers, a piece of thread, two pieces of thread,
   one wire, two wires.

2) Please draw pictures to show an arrangement of the materials.



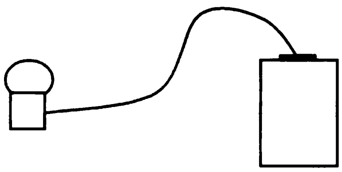
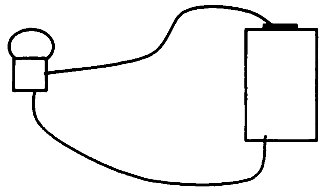
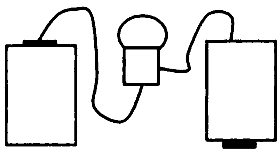
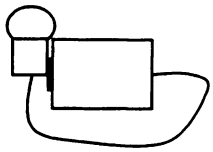
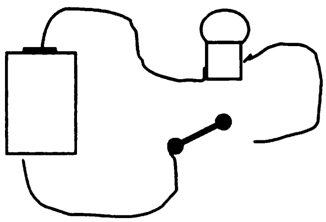
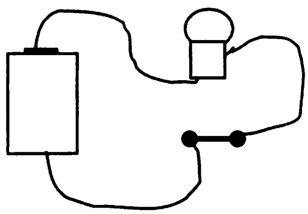
3) Explain why it will work.

____
____
____
____
____
____

4) What is the role of battery to light the bulb?

____
____
____

2. For each drawing, circle YES or NO to show if you think the bulb will light or not and explain why. Draw arrows to show where you think electricity is moving.

1) Will the bulb light? YES NO  Explain why:	2) Will the bulb light? YES NO  Explain why:
3) Will the bulb light? YES NO  Explain why:	4) Will the bulb light? YES NO  Explain why:
5) Will the bulb light? YES NO  Explain why:	6) Will the bulb light? YES NO  Explain why:

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