

**THE EFFECTS OF TYPES, QUANTITY, AND QUALITY OF QUESTIONING IN  
IMPROVING STUDENTS' UNDERSTANDING**

A Dissertation

by

ALPASLAN SAHIN

Submitted to the Office of Graduate Studies of  
Texas A&M University  
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

December 2007

Major Subject: Curriculum and Instruction

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Chair of Committee, Gerald Kulm  
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**ABSTRACT**

The Effects of Types, Quantity, and Quality of Questioning in Improving Students'

Understanding. (December 2007)

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Chair of Advisory Committee: Dr. Gerald Kulm

This research is based on the Middle School Mathematics Project (MSMP) funded by the Interagency Educational Research Initiative (IERI) through a grant to the American Association for the Advancement of Science (AAAS). Both teachers' video lessons and students' pre-and-post test scores were used to investigate the effects of teachers' types, quality, and quantity of questioning students' knowledge of algebra concepts and skills in variables, change, equality, and equations in middle school students in seventh and eighth grades. The study further explored the relationship between types of questioning, quality of questioning, and quantity of questioning. Later, teachers' intention of asking two types of questions, probing and guiding, and teachers' questioning acquisition methods were studied through face-to-face teacher interviews.

This dissertation used a mixed approach utilizing both quantitative and qualitative methods. The data were collected from 33 teachers in two different states, Texas and Delaware, who participated in the IERI project either during the 2002-2003, the 2003-2004, or the 2004-2005 school years. A total of 103 videotapes were obtained consisting of one to five lessons for each teacher. The teachers used one of four different textbooks: *MathThematics* (Billstein, et al., 1999), *Connected Mathematics* (Lappan, et al., 1998), *Mathematics: Applications and Connections Glencoe Algebra* (Collins, et al., 1998), or *Mathematics in Context (MiC)* (Romberg, et al., 1998).

The results showed that teachers' quality of probing questions affected students' achievements when other variables--teachers' teaching experience, textbook, and teachers' math preparation--were controlled. It was also found that AAAS' two highest rated two textbooks, CMP and MiC, affected students' understanding. Moreover, teachers' math preparation predicted student performance. Furthermore, quality and quantity of guiding questions and probing questions were significantly correlated with each other ( $p < 0.01$ ).

For the qualitative part, it was found that teachers' were asking what they intended to ask. In other words, they were aware of the role of questioning they were using. Also, there were several methods that seemed to be more used when acquiring questioning skills--watching and observing teachers, being in the field or from student-teacher experience, and workshops.

## DEDICATION

To my father, Davut Sahin,

For enlightening and cultivating me to be successful.

To my mother, Hatice Sahin,

For your nurture and unconditional love.

To my wife, Tugba Sahin,

For your endless support and encouragement.

To my brother Selcuk Sahin and my sisters Nilufer Ozen and Nevin Camuzcu,

For their trust in me.

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Finally, thank you to all the teachers of whom I was student, from grade-school to college. You have, in various ways, helped to shape the course of my life. I will always be grateful for teachers.

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## CHAPTER I

### INTRODUCTION

#### Background

In the year 2000, the National Council of Teachers of Mathematics (NCTM) set forth the principle for effective mathematics teaching: “Effective mathematics teaching requires understanding what students know and need to learn and then challenging and supporting them to learn it well” (NCTM, 2000, p. 4). Later, NCTM explained how to accomplish this by saying that teachers need to know “what questions to ask students having varied levels of expertise, and how to support students without taking over the process of thinking for them” (NCTM, 2000, p. 4). In other words, a powerful way for achieving these goals, according to the NCTM (1991), lies in the teachers’ ability to ask questions that will stimulate discourse in the mathematics classroom.

According to Mills, Rice, Berliner, and Rousseau (1980), the types of empirical studies done during 1970s can be grouped in five groups. From the current findings of contemporary research, this grouping seems valid today as well. In this study, I will only mention two of five groups of studies because they discuss the types of questions and their use in the classroom and how types and quality of questions effect students’ achievement, which are the issues addressed in my research.

In the first group of studies, authors found that low cognitive level of questions are the most common types of questions used by most teachers (Buraldi, 1998; Gall, 1970; Kawanaka & Stigler, 1999; Reynolds & Muijs, 1999).

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This dissertation follows the style of *Journal for Research in Mathematics Education*.

In other words, teachers ask more pre-determined or recall questions than higher-order or open questions. These studies found that asking higher-cognitive questions increases students' critical thinking. Moreover, cognitive classification methods seem helpful as training tools to improve teachers' questioning strategies toward a higher cognitive level (Gall, 1970; Martino & Maher, 1999; Vacc, 1993; Woolfolk, 1998). So, this first group of empirical studies provides useful background information about questions and their cognitive classifications.

The second group of studies examined the relationship between the use of question types and student achievement scores. These studies provided important, yet sometimes contradictory findings on the issue of questioning in the classroom. Carlsen (1991), for example, mentioned the results of three reviews on the issue. These three reviews have analyzed the results of various studies, particularly, experimental and quasi-experimental designs. In the first one, Winne (1979) looked at 18 studies using a simple tally method and found that there seemed to be no consistent effect of teachers' use of higher-order questions on students' achievement. In the second study, Redfield and Rousseau (1981) used meta-analysis to review approximately the same group of studies and concluded that the higher-order questions have a moderate positive effect on students' achievement. In other words, students learned more when they were exposed to higher-order questions (Aagard, 1973; Brophy & Good, 1985; Buggey, 1971). In the third study, Samson, Strykowski, Weinstein, and Walberg (1987) did a quantitative synthesis of 44 studies, roughly including the same studies as the two reviews and found similar results to Winne's results. Samson et al., (1987) concluded that asking higher-order questions has only a small effect on learning outcomes. According to the Rosenshine

(1976), however, who reviewed the research done in the early 1970s, students learned best when they were asked more factual or narrow questions. In addition to that, some studies have revealed that young students and low-income students benefit most from low-level questions while middle and high school students appear to have higher achievement when they are asked more high-level questions (Gall, 1984). Therefore, the empirical evidence relating higher-order questions to higher-level achievement is sparse, conflicting, and needs further investigation.

A substantial number of more recent studies have also investigated teachers' questioning of students and students' learning and understanding of mathematics (e.g., Harrop & Swinson, 2003; Ilaria, 2002; Martino & Maher, 1999, Yackel & Cobb, 1996). Some studies continued to investigate the relationship between types of teachers' questions and student learning (Gall, 1984; Kawanaka & Stigler, 1999). But, quantitative synthesis of experimental and quasi-experimental studies have shown that the relationship between the types or quality of teachers' questioning and students' achievement has yet to be settled by empirical studies (Dillon, 1982; Rosenshine, 1971; Samson et al., 1987). There have been a few studies that have found some possible support for the relationship between the types or quality of teachers' questioning on students' outcome. Attempts to show a relationship between student achievements and certain types or cognitive level of teachers' questions have been inconclusive. Although, there are some correlational studies showing positive relationship between certain types of teacher's questions and student's achievement (Gall, 1970; Rosenshine, 1971), experimental studies have been unable to establish causal linkages (Riley, 1980; Carlsen, 1991). The failure to demonstrate these linkages have been partially due to some

methodological and conceptual problems (Andre, 1979; Winne, 1979). Moreover, most of these studies have not used multiple outcome measures, relying on only factual recall to measure students' achievement and have often failed to use appropriate techniques (Andre, 1979). According to the Carlsen (1991), the studies done so far have not looked at other variables that interact with types or quality of questions. So, better designs and indicators of teachers' questioning, definition of content and context of the classroom, and students' outcomes, may result in more valid results on the relationship between teachers' questioning and students' achievement.

### **Relationship Between Teacher Questioning and Student Achievement**

In this study, I will define the types, quantity, and quality of teacher questions and their impact on students understanding. In order to obtain optimum effects of question type and quality, I will control for other variables such as teachers' experience, textbook, and teachers' mathematics preparation, which may have effects on student achievement. In contrast to the aforementioned studies, I will control for teacher background, textbook, school context variables and use multiple measures of student achievement. Therefore, this study will offer an opportunity to understand the role of questioning on students' learning and achievement.

### **Teachers' Intention and Habit of Questioning**

Questioning is one of the primary and most influential teaching skills that teachers use (Cotton, 1989). From the research literature, teacher questions have been found to be an indispensable part of classroom interaction (e.g., Edwards & Bowman, 1996). According to *Key Stage Three National Strategy* for foundation subjects (2002), teachers questioning is an important part of classroom teaching and learning and is the only short

way to gauge what student know and learn. In other words, one of the teachers' primary instructional strategies consists of using different types of questioning to determine whether students understand (Appalachian Educational Laboratory, 1994; Cotton, 1989). However, Sahin, Bullock, and Stables (2002) found that teachers use different kinds of skills during their teaching that they may not always be aware of. For instance, Voigt (1992) found that even though the teacher uses questions to elaborate certain meanings from students, the students may understand it differently. In other words, teachers ask many questions, but we are not sure what their intentions are in asking the questions or whether they are aware of why they are using particular questioning techniques.

Recent research on teachers has shown that a teacher's influence has been one of the most important variables for student learning (Quinn, 1999; Rivkin, Hanushyek, & Kain, 1998; Sanders & Rivers, 1996). In other words, as Dewey found in 1939, there was only one way to increase students' learning or achievement, increase the quality of real teaching. Research says that schools make a difference on students' outcome (Jesson et al., 1992; Mortimore et al., 1988). Of all the characteristics identified in effective schools, teaching approaches of teachers can enhance student achievement (Brown et al., 1995; Mortimore et al., 1988). Among those approaches, research in classroom discourse and dialogue indicates that classrooms are often dominated by teachers' questioning skill (Dillon, 1990; Kawanaka & Stigler, 1999; West & Pearson, 1994). In this interaction, the teacher mainly asks questions, the student answers them and this process goes on (Cooper & Simonds, 2003). Thus, one can say that the questioning method is one of the most common teaching skills among teachers (Cotton, 1989). In this study, how teachers acquire or develop their questioning skill will be investigated through face to face to

interviews.

### Theoretical Framework

Questions are a way that teachers use to encourage students to think about and develop mathematical concepts and procedures through “the negotiation of meaning for necessary condition of learning” (Voigt, 1992, p. 43). Voigt defined the negotiation of meaning as “the course of negotiation, the teacher and the students (or the students among themselves) accomplish relationships of mathematical meanings taken to be shared” (p. 35).

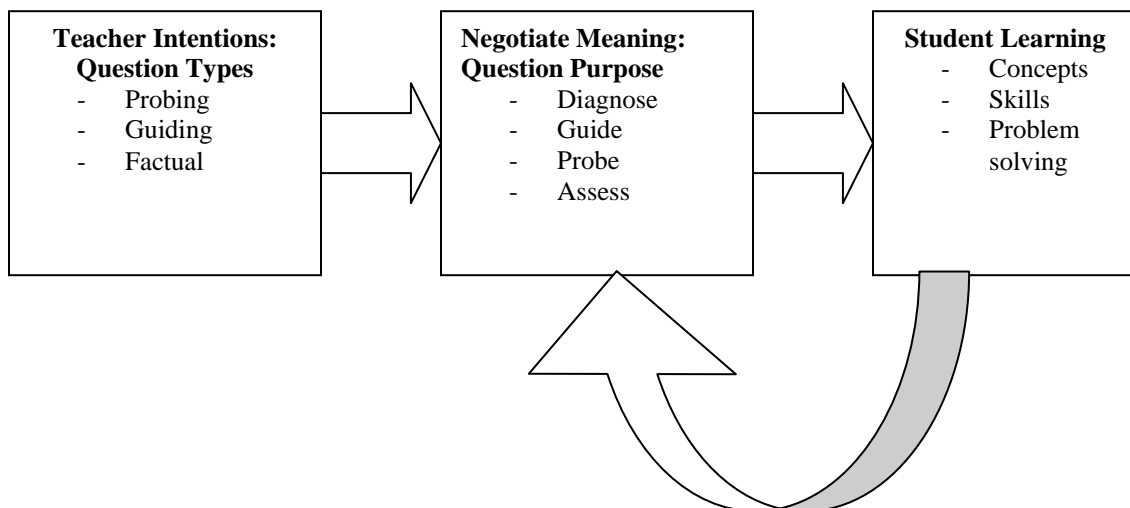


Figure 1. Models of the types and purposes of teacher questions.

As shown in the Figure 1, the theoretical model states that teachers have intentions to use various types of questions in order to negotiate meaning with students, which results in student learning. During the negotiation of meaning, questions serve several key functions: they allow teachers to (1) diagnose students’ prior knowledge or misconceptions, (2) probe for understanding, (3) guide student thinking, especially when



there is a difficulty or misunderstanding, and (4) informally assess student achievement of learning goals. Student learning can be classified into the achievement of skills, concepts, or solving problems. The types and purposes of questions have a direct relationship to these student learning outcomes. It should be noted that unless questions are directly related to the mathematical learning goal, they are unlikely to lead to student learning of that goal.

### **Purpose of the Study**

The purpose of this study is to explore the use of questioning in mathematics classrooms in public schools in Texas and Delaware. In particular, I am interested in focusing on probing and guiding questions defined by AAAS (2002) and effects of those questions on students' learning through looking at the relationship between quantity, types and quality of questions and students' achievement through using students' pre-and post-test results. My specific intent is, first, to measure the quality and quantity of two types of teacher's questions and then to examine the effect of different types of teachers' questions (probing, and guiding) on students' posttest achievement. Second, teachers' intentions will be examined through interviews to assist in interpreting the criteria and indicators developed by AAAS. Third, I will explore how teachers acquire questioning skills and what questioning strategies they use through face-to-face interviews. The primary data sources will be videotapes of classroom instruction and students' pre-and-post test scores.

### **Research Questions**

1. What is the effect of the quality of questions, quantity of questions, and types of questions on student achievement?

2. What is the relationship between the quality of questions, quantity of questions, and types of questions?
3. Do teachers actually ask what they intend to ask?
4. How do teachers acquire their habits or skill of questioning?

### **Definitions of Key Terms**

The following operational definitions are used in this study:

Types of Questions: Types of questions will be categorized as probing and guiding as defined by AAAS (See Appendix A). Probing questions:

- Encourage students *to express* their knowledge or understanding
- Encourage students *to clarify, justify, interpret, or represent* their knowledge or understanding
- Provides *opportunities for each student* (rather than just some students) to express their understanding.

Guiding Questions:

- The questions *relate to experiences or learning* with real world examples or representations.
- The questions *guide students to interpret and reason* about experiences or learning with real world examples or representations.
- The questions *provide hints or suggestions* to help students interpret and reason.

Quality of Questioning: According to Walsh and Sattes (2005), a quality question should have four characteristics: “(1) promote one or more carefully defined instructional purpose, (2) focus on important content, (3) facilitate thinking at a stipulated cognitive level, and (4) communicate clearly what is being asked” (p. 23). A measure of

the quality of questioning will be obtained by first rating each sighting using the indicators. The mean of the ratings will be calculated to obtain a teacher's quality of questioning.

Intention of Teachers' Questioning: Teachers' questions are used to elicit mathematical meanings from students (Voight, 1992). Teachers will be asked to indicate which of the AAAS indicators most closely matches their intended purpose for questions they ask. The degree of agreement between teachers' statements of what they intended with the AAAS indicators will be used as a measure of teacher intention..

Habit of Questioning: Habit of questioning is defined as the pattern and combination of the type and quality of a teachers' use of questioning, across lesson content and contexts.

Teachers' Experience: Teacher experience is the numbers of the years taught regardless of the grade levels.

Teachers' Mathematics Preparation is defined as the number of math or math related courses the teachers completed prior to the study.

### **Significance and Implication of Study**

The information teachers provide in their daily teaching practices, based on videotapes, is crucial to capture what and how they are teaching for better mathematics education. Questioning is one of most common teaching methods at all grade levels (Cotton, 1989). According to Kerry (1982), a teacher probably asks about one thousand questions per week. Moreover, since classroom discourse is dominated by teachers and student talk is mostly in the form of responses to teacher questions (Kawanaka & Stigler, 1999), one can say that the importance of the teacher's questioning strategy is immense.

Previous studies done on questioning have focused more on counting the number and types of questions. In this, study, I will investigate how questioning operates in the mathematics classroom beyond counting or categorizing questions, using more precise indicators for types and quality of questions in addition to how students learn. Moreover, this study will investigate how aware teachers are of the use of quality and types of questions. Furthermore, helpful knowledge will be obtained about how teachers acquire habits of questioning. Therefore, mathematics educators will be able to develop better preservice and professional development strategies to improve teacher questioning. Thus, one will have a more specific perspective of mathematics teaching in middle schools as well as an understanding of the impact of teachers' questioning on students' achievement.

### **Limitations and Delimitations**

1. The subjects in this study were limited to middle school mathematics teachers.
2. This study was limited to the experiences and practices of the volunteer teachers from convenience samples in Texas and Delaware. Therefore, the study may not be generalized to other teachers and schools.
3. All variables, subjects and conditions not so specified were considered beyond the scope of this study.
4. The types of questions were only limited to two; probing and guiding.
5. Some of the teacher information was missing due to either their lack of response or lack of communication.
6. Due to the goals of the AAAS study, the project staff only used a teacher microphone. Therefore, some of students' responses were not clear.
7. There was a time lag between the actual lesson taught and the interviews.

## **CHAPTER II**

### **LITERATURE REVIEW**

#### **Introduction**

The purpose of this study is to examine teachers' questioning strategy in mathematics classrooms and offer a mechanism for teacher reflection. Specifically, the study investigates how teachers' quality, quantity, and two types of questioning (probing and guiding) affect students' understanding of middle school math topics associated with curriculum choice, teachers' teaching experience, and teachers' math preparations. Moreover, how and why teachers use questioning and how they acquire questioning skills are investigated through teachers' interviews. Following the structure laid out in the first chapter, this chapter expounds on NCTM's (2000) view of the influences and enactments of teachers' questioning. In the first section, I discuss general issues surrounding the teachers' questioning strategy and its history. Next, I define types, quality, and quantity of questioning. I then present and discuss past and contemporary research on the effects of teachers' questioning on students' achievements. In the next section, I define control variables and summarize how control variables are related to student achievements and why I chose them for this study. The next section describes the relationship between teachers' intentions and habit of questioning. Within this section, I discuss previous research and the importance of how and why teachers acquire the skill of questioning. Finally, I summarize how all of these factors are important not only for teacher education but also for better students learning.

#### **Teachers' Questioning**

One of the purposes of any instructional strategy is to help students retrieve what

they already know about a subject being discussed (Marzano, Pickering, & Pollock, 2001). In other words, one of the goals of teachers is to activate prior student knowledge, which is critical to learning of all types (Marzano, Pickering, & Pollock, 2001). Indeed, according to the NCTM (2000), “effective mathematics teaching requires *understanding what students know* and need to learn and then challenging and supporting them to learn it well” (p. 4). NCTM (2000) gives some clues on how to do effective mathematics teaching in the *Teaching Principle*. In addition to other techniques to teach effectively such as selecting and using suitable curricular materials, using appropriate instructional tools and techniques, the teaching principle states that a crucial teaching strategy is to know what questions to ask students to reveal and to retrieve information. Why is questioning so important? What have educational researchers found about the role of teachers’ questioning? More specifically, what are the roles of teachers’ types, quantity, and quality of questioning on students outcomes? Are teachers aware of the role of questioning? And finally, how do they acquire habit of questioning?

### **Why Questions?**

The role of questions to improve students’ understanding has been recognized for centuries and the use of questioning in teaching is as old as the Greek Philosopher, Socrates in the fifth century B.C. (Harrop & Swinson, 2003). Stevens (1912) found that approximately eighty percent of a teacher’s teaching in school was spent in asking questions. Recent research on teacher questioning behaviors and patterns shows that this has not changed (e.g., Brualdi, 1998; Kawanaka & Stigler, 1999). In other words, classrooms are still dominated with mostly teacher talk (Kawanaka & Stigler, 1999).

Questions serve many purposes, such as provoking students and making them

listen carefully, analyzing their thoughts and thinking critically (Ramsey, Gabbard, Clawson, Lee, & Henson, 1990), initiating discussion and reviewing material (Cotton, 1989), challenging students to discover their ideas, inviting students to take risks, motivating and evaluating students (Schurr, 2000). The issue of questioning has also received attention in contemporary studies of education (e.g., Harrop & Swinson, 2003; Ilaria, 2002; Kawanaka & Stigler, 1999; Martino & Maher, 1994; Sahin, Bullock, & Stables, 2002). The importance of questioning cannot be underestimated. Burns (1985), for instance, deems that questioning is an important strategy in establishing a classroom atmosphere that is conducive to developing mathematical thinking in students. Hence, it is not surprising that questioning has been thought to be a good measure of a teacher's quality for nearly a century (Kawanaka & Stigler, 1999). As Myhill and Dunkin (2002) illustrate, "Just like a good barrister, a *good* teacher knows how to use questions for maximum impact" on students (emphasis added. p. 8). Harrop and Swinson (2003) also agree that asking good questions is one of the most important skills for teachers. Our understanding of the topic of questioning should be advanced and the amount of attention given to it should be increased.

### *Types of Questioning*

There has been a substantial amount of research done on the frequency, types, and categorization of teachers' questions (Cotton, 1989; Moyer & Milewicz, 2002). In this research, the categorization of the teachers' questioning is usually based on the cognitive level of students' understanding as Ilaria, (2002) used. According to Woolfolk (1998), categorization of the teachers' questions as divergent and convergent have different implications such as having many possible answers and having only one answer,

respectively. Cotton (1989) confirmed that a substantial amount of research has focused on dualistic definitions of the questions. On the other hand, Black, (2001) summarized the research done on types of questions and explained this dualistic system. There are two broad types (dualistic) of teacher questions: low-level and high-level. Low level questions are also called closed, direct, recall, and knowledge question. One can define low-level questions from research as those requiring students to recall specific knowledge from their text or a teacher's questions or notes. This type has been the most common question type in classrooms since the beginning of the twentieth century (Steven, 1912) and used between fifty and eighty percent of the time (Black, 2001; Gall, 1984; Kawanaka & Stigler, 1999; Sahin & Kulm, 2006).

Black (2001) mentions the definition of high-level questions, also called open-ended, interpretive, evaluative, inquiry, inferential, and synthesis, as the ones requiring students to elaborate the information given and to answer with deeper thinking and evidence. According to researchers, about twenty percent of teachers' questions are high-level questions (Brualdi, 1998; Gall, 1984; Kawanaka & Stigler, 1999; Newman, 1988; Sahin & Kulm, 2006).

Another type of categorization of questions is according to a hierarchy of knowledge (Ilaria, 2002). The most common used one is Bloom's (1956) taxonomy. In Bloom's taxonomy, the questions are ordered or categorized based on the content or complexity of their meanings (Woolfolk, 1998). For example, Wilen (1987) discussed two types of questions that align with Bloom's (1956) taxonomy. In Wilen's study, low-level questions match Bloom's knowledge level where the emphasis is on recalling specific facts and information whereas, high-level teachers' questions require student's



thinking in the four or five levels above knowledge level; comprehension, application, analysis, synthesis, and evaluation . In summary, even though there are different types of categorization most researchers agree on similar types of categorization and questioning.

### *Probing Questions*

Although, the role and importance of probing questions has long been known by educators, the use of probing questions is not a frequent practice by many teachers. (Newmann, 1988). Probing questions is a type of open-ended or higher order questions that not only extend students' knowledge beyond factual recall and repeating learned skills, but also push students to use previous knowledge to explore and develop new concepts and procedures (MSDE, 1991). "Teachers who encourage students to elaborate on and explain their thinking through the use of probing questions promote learning because such questions push students to think more deeply about the topic being discussed" (Krupa, Selman, & Jaquette, 1985, p. 453). On the other hand, Martino and Maher (1999) point out a different function of the use of probing questions. In the study, they found that questions in probing format can be used for student justification of solutions and re-examination of their original solution. Therefore, students can provide more adequate explanation, justification, and/or generalization (Martino & Maher, 1999). In other words, asking probing questions is a useful teaching method to help teachers explore what students are thinking (Moyer & Milewicz, 2002)

The characteristics of probing questions, in these studies, were related to the purpose of teaching rather than descriptions of probing question. In this study, I used the following purposes as the indicators of probing questions developed by AAAS (2002)

- Encourage students *to express* their knowledge or understanding

- Encourage students *to clarify, justify, interpret, or represent* their knowledge or understanding
- Provides *opportunities for each student* (rather than just some students) to express their understanding.

### *Guiding Questions*

There are few studies that appeared to focus particularly on *guiding* questions. Kawanaka and Stigler (1999) discussed guiding questions, characterizing them as those that guide students to discuss problems and derive mathematical concepts and procedures, thereby functioning to direct students to use mathematical concepts and procedures to solve problems. Ortenzi (2002) mentions *leading* or *helping* questions, which could also be classified as guiding. When a student is not sure how to solve or proceed with the problem, the teacher lead the student with a question such as ‘which method do you need to use now?’ Ortenzi (2002) added, however, that through this kind of questioning the teacher may lead students into convergent thinking the way the teacher wants them to think. Similarly, with helping questions, when the student has a problem with choosing between two methods for adding quantities, the teacher can intervene and help the student by saying, for instance, ‘I think this method is a good choice here, isn’t it?’ In these three question typologies (guiding, leading, and helping), there is a partial overlap. Guiding questions are similar to leading questions, which can promote student thinking. Helping questions provide more direct information from the teacher when the student encounters difficulty. Thus, I have adopted the following criteria for guiding questions as AAAS (2002) did:

- The questions *relate to experiences or learning* with real world examples or

representations.

- The questions *guide students to interpret and reason* about experiences or learning with real world examples or representations.
- The questions *provide hints or suggestions* to help students to interpret and reason.

### *Quality of Questioning*

Research findings indicate that teachers ask two to three questions per minute (Appalachia Educational Laboratory, 1994; Gall, 1971). In other words, students are supposed to answer a question within 20 or 30 seconds. Thus, one can say that quality questions are important in terms of actively engaging students in learning work and preparing those (Walsh & Sattes, 2005).

Walsh and Sattes (2005) discuss previous research regarding the criteria for quality questioning. For instance, Dillon (1983) discussed effective questioning in terms of advancing learning and thinking. According to Dillon, these questions are purposeful, engaging, and consequential. Quality questions are aligned with the objectives of the lesson, promote children' interest and class involvement, and result in learning outcome (Anderson & Krathwohl, 2001). Walsh and Sattes (2005) provide four characteristics of quality questions: (1) promote one or more carefully defined instructional purposes, (2) focus on important content, (3) facilitate thinking at a stipulated cognitive level, and (4) communicate clearly what is being asked (p. 23).

### **The Relationship between Teachers' Types, Quantity, and Quality of Questioning and Students' Achievement**

Even though asking and answering questions are very common teaching activities

among teachers and students, researchers have found little evidence on how the types, quantity, and quality of teachers' questioning affect learners (Carlsen, 1991; Dillon, 1982; Kawanaka & Stigler, 1999; Samson et al., 1987). The research does not indicate that one type of question is necessarily superior to the other (Carlsen, 1991; Gall, 1984; Winne, 1979).

Winne (1979) reviewed 18 experimental and quasi-experimental studies on this issue in order to determine which question types helped students to learn better. In that study, Winne (1979) defined higher order or divergent questions as the ones requiring "the student to mentally manipulate bits of information previously learned to create an answer or to support an answer with logically reasoned evidence" (p. 14). This definition of higher-order questions matched the application, analysis, synthesis, and evaluation levels of Bloom's taxonomy. Lower-order or convergent questions were defined as those asking for exact recall or recognition of fact previously discussed or read by a teacher. This definition aligned with the levels of knowledge and comprehension in Bloom's taxonomy. Winne used tallying method and categorized studies into three groups: a) studies yielding significant results, b) either positive or negative results, c) those yielding non-significant results. When the studies in each group were compared, there were no differences in student outcomes related to whether the teacher asked more higher-order or lower-order questions.

On the other hand, Redfield and Rousseau (1981) used a meta-analysis technique to review almost the same group of experimental and quasi-experimental studies (18 out of 20 were the same as in Winne's study). The studies were categorized into two groups as skills or training experiments according to Campell and Stanley's (1966) criteria for

internal validity. There were two kinds of studies: training experiments and skills experiments. Teacher training was defined as the independent variable in training experiments whereas, frequency and manner of a teaching skill (i.e., higher or lower cognitive questions) was defined as an independent variable in the skills experiments. In both, student achievement was the dependent variable. The result showed that in some experiments the use of higher-cognitive questions helped student achievement increase when teachers asked more higher-order questions, and in some other experiments, the use of factual questions was more helpful when the teachers used more factual questions. However, the majority of experiments favored higher-order questions. In contrast to the Winne's study, this meta-analysis demonstrated that teachers' predominant use of higher cognitive questions has a positive effect on student scores. The overall findings supported the previous conclusions (e.g., Gall, 1970). In summary, in an environment where teachers were trained in questioning skills and in which the validity of program implementation was carefully monitored, student achievement can be improved when the teachers asked more higher- than lower-level questions (Redfield & Rousseau, 1981).

Samson, Strykowski, Weinstein, and Wahlberg, (1987) did a similar study, synthesizing forty-four empirical studies including most of Redfield and Rousseau (1981) and Winne (1979) studies, again to determine whether teachers' use of predominantly higher-cognitive questions have a greater effect on students' achievement a lower cognitive questions. In this study, selection was similar to the two other studies. First, the dependent variable was student achievement as in the other two studies. Moreover, the independent variable was teachers' types of questioning as higher cognitive or lower cognitive defined by Winne (1979). Third, there was sufficient data to calculate an effect

size. Samson et al., (1987) found that the effects of higher cognitive questioning had a small positive effect on student achievement. According to Samson et al., (1987), these findings have not had much educational importance.

Although all three groups of studies found somewhat different results, it seemed clear that the effects of questions types, either higher-order or lower-order, on student achievement still remained unanswered. Carlsen (1991), in a review of questioning, proposed three possible reasons why all these studies have inconclusive results on the relationship between teachers' types of questions and students' achievement. First, the role of questions on student achievement was so weak that finding the effect of it was very method dependent. In other words, the teachers' questioning technique was not powerful enough to effect students' achievement by itself. Other variables such as content, context, the types of students, types of textbook, teachers' experience, and so on should be controlled or randomized in discussing the results of studies on questioning.

As a second explanation to the inconclusive results, Carlsen stated that the cognitive level of the question was only one part of what was really important about a question. The content of the questions was also important because age, grade level, and other variables were also related to the cognitive level of the questions. But in most of the studies, cognitive level was considered independent from other aspects of questioning. Perhaps higher-order questions promoted students learning and achievement only when they meet certain criteria of difficulty, age of students, complexity, and so on. In other words, questioning itself was not enough powerfull to affect student's learning if other conditions of learning did not exist together in the classroom.

As a third possible explanation for inconsistent results, Carlsen considered a

socio-linguistic perspective rather than a process-product paradigm, emphasizing the importance of the context of the questions being asked during a lesson. Carlsen explained this with an example. The answer to the question “what are the functions of the human skeleton?” would be classified as a higher-order question according to most of the process-product researchers. But what if the teacher had taught the function of the human skeleton in a previous lesson and had told the students that there would be a test on the topic. According to socio-linguistic perspective, Carlsen pointed out that “the content of the question cannot be assessed without reference to a broader linguistic context and the knowledge of the speakers” (p.166). Also, the observation of the class will not be objective because the observer may not be familiar with the subject-matter content, the students, and so on. In other words, the result of the observation may not be threat-free, making the results of the study susceptible to error or misinterpretation. In summary, Carlsen (1991) pointed out several important issues on why process-product research failed to find conclusive results. In other words, the questioning strategy or question, itself, may not be strong enough to change student’s understanding or to affect test results without interacting or being used with other factors such as in a classroom with knowledgeable teachers, reform-based textbook.

### **Conceptual Variables Influencing the Effects of Types, Quantity, and Quality of Teachers’ Questioning and Students’ Achievement**

#### *Textbook*

Recent data from the Third International Mathematics and Science Study (Schmidt, McKnight, & Raizen, 1997) demonstrated that curriculum materials make a difference in achievement. Most curriculum materials or textbooks suffer from a lack of

coherence and focus. On the other hand, the textbook is the primary guide for implementing the curriculum for most of teachers. According to the Project 2061, a textbook should have following three roles:

First, good textbooks can play a central role in improving mathematics education for all students; second, the quality of mathematics textbooks should be judged mainly on their effectiveness in helping students to achieve important mathematics learning goals for which there is a broad national consensus; and, third, an in-depth analysis of much more than a textbook's content coverage would be required to evaluate whether there is potential for students' actually learning the desired subject matter (AAAS, 2000, p. 1).

In this context, recent studies found that standard-based, high-quality textbooks enhanced students' achievement (Kulm & Capraro, 2004; Reys, Reys, Lappan, Holliday, & Wasman, 2003). Trafton, Reys, and Wasman (2001) proposed explanations of what this high quality meant by saying that these were six characteristics that standard-based curriculum should have comprehensiveness, coherence, depthness in developing ideas, promotion of sense making, engagement of students, and motivation for learning. In other words, textbooks influence students' learning both directly and indirectly through teachers' providing mathematics content knowledge and teaching strategies (Kulm & Capraro, 2004; Reys et al., 2003). In a summary of the goals of a professional development research project, DeBoer et al., (2004) proposed a linear relationship between the following four aspects: professional development together with *curriculum materials*, *teacher knowledge*, skills and attitude, teaching behavior, and students' learning. A study conducted by Project 2061 examined the quality of 13 textbooks based



on a total of 24 criteria classified into seven categories: identifying a sense of purpose, building on student ideas about mathematics, engaging students in mathematics, developing mathematical ideas, promoting student thinking about mathematics, assessing student progress in mathematics, and enhancing the mathematics learning goal (AAAS, 2000). Four textbooks that were used in this study ranked high, high, medium, and low, respectively: Connected Mathematics Project (CMP) (Lappan, Fey, Fitzgerald, Friel, & Phillips, 1998), Math in Context (MiC) (Romberg, et al., 1998). Middle School Math Thematics (Billstein, Lowery, Montoya, Williams, & Williamson, 1999) and Mathematics: Applications and Connections (Collins, et al., 1999). Connected Mathematics and Math in Context had a median rating of more than 2.5 on a scale of 0-3 points for all of the 24 instructional criteria for all six benchmarks. Middle Grade Math Mathematics was ranked as partial satisfactory with a score ranged from 1.3 to 3.0 on the corresponding criteria, while Mathematics: Applications and Connections (Glencoe) were graded as unsatisfactory with a score range from 0.3 to 2.6 on the corresponding criteria.

Empirical findings by Kulm and Capraro (2004) reported that despite the variation of enacted curriculum delivered by the teachers, student achievement was related to the rankings of the textbooks rated by AAAS. In other words, the higher rated textbooks will end up with higher achiever students.

### *Teaching Experience and Quality*

Another factor that may affect student achievement is the length of teaching experience. Even though some research indicates that school inputs make little difference in student learning, a growing body of research shows that schools can make a difference, and an extensive portion of that difference is due to teachers (Darling-Hammond, 2000).

Recent studies of teacher effects at the classroom level using the Tennessee Value-Added Assessment System and a similar data base in Dallas, Texas, have found that differential teacher effectiveness is a strong determinant of differences in student learning (Jordan, Mendro, & Weerasinghe, 1997; Sanders & Rivers, 1996; Wright, Horn, & Sanders, 1997). Students who are assigned to several ineffective teachers in a row have significantly lower achievement gains than those who are assigned to several highly effective teachers in sequence (Sanders & Rivers, 1996).

The teacher factor has been the topic for a substantial amount of research over the last 50 years. Teacher qualities that have been examined for their relationship to student learning include measures of academic ability, years of education, years of teaching experience, measures of subject matter and teaching knowledge, certification status, and teaching behaviors in the classroom (Darling-Hammond, 2000). The results of these studies have been mixed; however, some trends have emerged in recent years.

Greenwald, Hedges, and Laine (1996) conducted meta-analyses on the following school resources that were generally associated with student achievement: administrator qualifications, class size... teacher education, *teaching experience*, and teacher salaries. They used ERIC database to search for the period 1966-1993. The conclusion was that school resources were systematically related to student achievement. In addition, they found that quality of teachers (teacher ability, teacher education, and teacher experience) had very strong positive relations to student achievement.

Some studies have found that there was a relationship between the effects of teachers' experience and student learning (Klitgaard & Hall, 1974; Murnane & Phillips, 1981), but not always a significant one or a perfectly linear one. Some studies have

established that inexperienced teachers (those with less than three years of experience) were typically less effective than more senior teachers (Rosenholtz, 1986). A possible explanation of this non-linear relationship in experience effects was that veteran teachers have not always continued to learn and may have felt tired in their jobs (Darling-Hammond, 2000). Veteran teachers in settings that emphasized continual learning and collaboration continue to improve their performance (Rosenholtz, 1984). Darling-Hammond gave an example of how some new teachers did as well as veteran teachers:

Similarly, very well-prepared beginning teachers can be highly effective. For example, some recent studies of 5-year teacher education programs--programs that include a bachelor's degree in the discipline and master's in education as well as a year-long student teaching placement--have found graduates to be more confident than graduates of 4-year programs and as effective as more senior teachers (Andrew & Schwab, 1995; Denton & Peters, 1988, p. 9).

### *Teachers' Mathematics Preparation*

Spencer (1910) asked "What knowledge is of most worth?" Answers have varied over the years but it seemed that the professional community was close to agreement regarding what teachers needed to know and be able to do (Strudler, McKinney, Jones, & Quinn, 1999). Some researchers continued to try to find the correct response to Spencer's question, believing that finding the link between teacher education and student achievement was worthwhile (Strudler, McKinney, Jones, & Quinn, 1999). Indeed, it has been shown that the teacher's influence was one of the most important variables in student learning (Rivkin, Hanushek, & Kain, 1998; Sanders & Rivers, 1996; Strudler, McKinney, Jones, & Quinn, 1999). As Dewey (1939) said, there was only one way to increase students' learning or achievement: increase the quality of real teaching.

In a cross cultural study between United States and China, Ma (1999) found

powerful evidence that mathematical content knowledge of teachers played a vital role in mathematics teaching. According to Ma, a conception of mathematical understanding meant the knowledge of teachers so that they could teach mathematics ideas clearly to students. Howe (1998) summarized the problem that existed in mathematics education in the United States:

Education involves two fundamental ingredients: subject matter and students. Teaching is the art of getting the student to learn the subject matter. Doing this successfully requires excellent understanding of both. As simple and obvious as this proposition may seem, it is often forgotten in discussions of mathematics education in the U.S., and one of the two core ingredients is emphasized over the other. In K-12 education, the tendency is to emphasize knowing students over knowing subject matter, while at the university level the emphasis is frequently the opposite (p. 585).

So, there is a link between teacher's knowledge and student's achievement. Such a link has been asserted in the No Child Left behind Act (2001) as the primary purpose of teacher education. One of the requirements of this act for a qualified teacher was to pass a subject matter test. Prior to the enactment of NCLB, the American Mathematical Society proposed that every teacher should have a concrete understanding of the mathematics they were to teach (Howe, 1998). Ma (1999), Ball (1991), Monk (1994), and Monk and King (1994) support the claim that knowledge of subject matter was an important variable in accounting for variance between more effective and less effective teachers. Without content knowledge, it was hardly possible to teach the content knowledge to students.

### **Summary of Conceptual Variables**

#### *Teachers' Intention*

According to Cotton (1989), teachers used questioning strategies for many

reasons, including evaluating students' learning, checking their class work and homework, and reviewing and summarizing lessons. In addition, teachers question students to motivate them to pay attention and learn, to develop their thinking skills, and to stimulate them to inquire and investigate on their own. But Cotton said that teachers usually can not use these questioning methods efficiently. Questioning operates within an interaction frame (Barnes & Todd, 1995), and its function showed variations. Young (1992) identified teachers-students' questions-answer process as Guess What Teacher Thinks, in which the teacher has the control of the topic and the pupil was expected to guess what the teacher had in his/her mind. Thus, the pupil's answer was judged according to the closeness of the framework that the teacher has in his/her mind. So, there was a link between the thought in the teachers' mind and students' answer. In other words, the teachers' intention was the one that the teachers expected to hear from students.

There is a growing body of research focusing on teachers' beliefs because the importance of the relationship between teachers' beliefs and their classroom practices is becoming widely accepted in education (Calderhead, 1996; Fang, 1996; Pajares, 1992; Poulson *et al.*, 2001). Researchers have used the term 'beliefs' in different ways. It was interpreted as perceptions, assumptions, implicit and explicit theories, judgments, opinions and more (Calderhead, 1996; Kagan, 1992; Pajares, 1992).

According to Sahin, Bullock, and Stables (2002), classroom discourse was complex and teachers used many skills during their questioning. Also, they may not be aware of some of them. On the other hand, research has found that teachers' questioning was one of the primary and most influential teaching skills they used (Cotton, 1989). For

instance, Voigt (1992) found that even though the teacher used questions to elaborate certain meanings from students, they understood it differently. In other words, teachers asked many questions, but we were not sure what their intentions were in asking the questions or whether they were aware of why they are posing certain questions. In this study, the role of teachers' questioning in a teachers' mind was explored by comparing their idea or intention of asking questions with their practice by looking at indicators of questions.

### *Skill (Habit) of Questioning*

Research indicates that schools make a difference on student outcome (Jesson et al., 1992; Mortimore et al., 1988). Of all the characteristics identified in effective schools, teaching approaches can most enhance student achievement (Brown et al., 1995; Mortimore et al., 1988). Among those approaches, research in classroom discourse and dialogue indicated that classrooms are often dominated by teachers' questioning skill (Dillon, 1990; Kawanaka & Stigler, 1999; West & Pearson, 1994). In this interaction, the teacher mostly asked questions, the student answered and this process went on (Cooper & Simonds, 2003). So, one can say that the questioning method is one of the most common teaching skills among teachers.

Recently, the importance of questioning skills development for practicing teachers has been emphasized in the publication of the *Key Stage Three National Strategy* for foundation subjects (2002). The introduction to this issue identified five reasons why questioning was a critical skill: (1) it was the most common form of interaction between teacher and pupil, (2) it was the element or most used teachers' teaching strategy in every type and model of lesson (3) it was a key strategy of providing appropriate challenge for

pupils, (4) it was an important way to increase the quality of teaching, and (5) it was the most immediate and accessible way for a teacher to see learning and progress. In other words, teachers questioning skill was an important part of classroom teaching and learning and was the only a practical way to gauge what student know and learn.

### **Summary**

The literature on questioning and other conceptual variables provides insight into the structure and function of the types, quality, and quantity of questioning on students learning. From this literature, it is seen that conceptual variables; teachers' math preparation knowledge, textbook, and teachers' teaching experiences have an effect on the dependent variables.

## CHAPTER III

### METHODOLOGY

This study was designed to investigate how teachers' quality, quantity, and types of questioning influenced student achievement. Moreover, teachers' intention was studied to determine if they asked the types of questions they intended to ask. Finally, teachers' habit of questioning and their acquisition of this behavior were examined. The data were collected from 33 seventh and eighth grade teachers in two different states, Texas and Delaware, who participated in the IERI project either during the 2002-2003, or during 2003-2004, or during 2004-2005 school years. Both qualitative and quantitative data were collected and analyzed. A total of 103 videotapes were obtained; consisting of one to five lessons for each teacher. The teachers used one of four different textbooks: *MathThematics* (Billstein, et al., 1999), *Connected Mathematics* (Lappan, et al., 1998), *Mathematics: Applications and Connections Glencoe Algebra* (Collins, et al., 1998), or *Mathematics in Context (MiC)* (Romberg et al., 1998).

The procedures, variables, participants, lesson selection, instrumentation, and data analysis are discussed in detail in this chapter.

#### Procedures

This study was designed to use the data of a 5-year longitudinal project of an Interagency Educational Research Initiative (IERI) Project, which was in collaboration with Texas A & M University, The University of Delaware, and Project 2061 of the American Association for the Advancement of Science (AAAS). The overall goal of the project was to explore the hypotheses that "the interactions among teachers, curriculum materials, professional development, and ongoing support for teachers that can lead to



lasting improvements in students' learning" (Nelson, Kulm, & Manon, 2000, p. 2). Information about the types of curriculum, teachers' experience, and teachers' mathematics preparation knowledge were obtained from the project data base. In addition, data on teacher quality measures and student achievement were also obtained from the project.

### **Variables**

In this study, the independent variables were (a) teachers' types of questioning, b) quantity of teachers' questioning, and (c) teachers' quality of questioning, (d) teachers' experience, (e) teachers' mathematics preparation, and (f) textbook. Student achievement was used as the dependent variable. According to Walsh and Sattes (2005), a quality question should have four characteristics: "(1) promote one or more carefully defined instructional purposes, (2) focus on important content, (3) facilitate thinking at a stipulated cognitive level, and (4) communicate clearly what is being asked" (p. 23). The types and quality of questions were determined by the indicators used in the IERI project (Nelson et al., 2000). Teachers' types of questions were categorized as probing and guiding as defined by criteria developed by the project (AAAS, 2002). Criterion V-A focused on teacher questions that *encouraged students to explain their ideas*. This criterion reflected teachers' use of probing and follow-up questions to encourage each student to express, clarify, justify, interpret, and represent his/her knowledge/understanding of the learning goals (e.g. with tasks, real world examples; representations, and/or readings related to the learning goals) and get feedback. In this context, the indicators that defined the quality of questions for Criterion V-A were the following:

**Indicator 1:** The teaching encourages students to express their knowledge/understanding relevant to the learning goals.

**Indicator 2:** The teaching encourages students not only to express but also to clarify, justify, interpret, and/or represent their knowledge/understanding.

**Indicator 3:** The teaching provides opportunities for each student (rather than just some students) to clarify, justify, interpret, and/or represent their knowledge/understanding.

Criterion V-B reflected teachers' use of questions that *guide interpretation and reasoning* of students. Indicators for Criterion V-B that defined the quality of teaching that used questions to guide students thinking regarding learning goals. V-B were the following:

**Indicator 1:** The teaching includes specific questions and/or tasks to address a mathematical dilemma that confronts the student(s) and to support student progress toward a more complete conceptual understanding of the learning goals without leading.

**Indicator 2:** The guiding questions/tasks are responsive to evidence of student thinking rather than generic in nature and directly target the students' mathematical dilemma regarding the learning goals.

**Indicator 3:** The teacher is persistent in supporting student progress toward a deeper understanding of the learning goals. .

Teacher questions were used to elicit mathematical meanings from students (Voigt, 1992). Teachers were asked to indicate which of the AAAS indicators most closely matches their intended purpose for questions they ask. The degree of agreement

between teachers' statements of what they intended with the AAAS indicators was used as a measure of teacher intention.

Teachers' habit of questioning is defined as the pattern and combination of the type, quantity, and quality of a teachers' use of questioning, across lesson content and contexts.

### **Participants**

The data analyzed in this study were collected through systematic analysis and coding of videotaped lessons taught by a convenience sample consisting of 33 (7 from Texas and 26 from Delaware) 7<sup>th</sup> and 8<sup>th</sup> grade teachers. There were 15 public schools (7 from Texas and 8 from Delaware) as part of a 5-year longitudinal study. Specifically, since the study focuses on the content of Algebra, the 33 7<sup>th</sup> and 8<sup>th</sup> grade teachers who taught lessons on this content were selected. Table 1 presents a summary of the demographic data of the teachers.

Table 1

*Teachers' Demographic Data*

Teachers' ID	Textbook	# of Courses Taken	# of Years Teaching	# of Algebra Lesson	Year
1	CMP	4	0-5	5	2002-03
2	MiC	3	6-10	2	2002-03
3	Glencoe	4	6-10	3	2002-03
4	CMP	3	6-10	4	2002-03
5	MiC	Missing	Missing	3	2002-03
6	MiC	3	0-5	3	2002-03
7	CMP	Missing	Missing	4	2002-03
8	MiC	6	6-10	3	2002-03
9	MTh	12	11-15	2	2002-03
10	MiC	1	6-10	3	2002-03
11	CMP	Missing	Missing	4	2002-03
12	CMP	Missing	Missing	4	2002-03

Table 1 continued

Teachers' ID	Textbook	# of Courses Taken	# of Years Teaching	# of Algebra Lesson	Year
13	Glencoe	6	0-5	4	2002-03
14	CMP	5	0-5	4	2002-03
15	MiC	6	11-15	3	2002-03
16	CMP	5	11-15	5	2002-03
17	CMP	6	11-15	4	2002-03
18	CMP	Missing	Mssing	3	2002-03
19	Glenceo	16	6-10	3	2003-04
20	CMP	4	6-10	3	2003-04
21	MiC	Missing	Missing	3	2003-04
22	MiC	1	0-5	3	2003-04
23	MiC	6	6-10	2	2003-04
24	MTh	4	6-10	2	2003-04
25	MiC	Missing	Missing	2	2003-04

Table 1 continued

Teachers' ID	Textbook	# of Courses Taken	# of Years Teaching	# of Algebra Lesson	Year
26	MiC	Missing	Missing	2	2003-04
27	CMP	9	15-20	3	2003-04
28	CMP	Missing	Missing	3	2003-04
29	Glencoe	6	6-10	1	2003-04
30	CMP	Missing	Missing	3	2003-04
31	MiC	8	6-10	3	2003-04
32	MiC	Missing	Missing	3	2003-04
33	CMP	6	11-15	5	2003-04

Six teachers were new teachers. Sixteen teachers had different years of experience varying from 6 years to 20. Eleven teachers' information was missing on years of teaching. Four teachers were male; 29 teachers were female. Some of the teachers had taken several mathematics courses during either their undergraduate or master programs; others had completed only a few math courses. Ten teachers' information was missing concerning the number of math courses taken.

### Lesson Selection

The lessons used in this study were videotaped in 2002-2003, 2003-2004, and 2004-2005. For this study, videotapes of 103 (29 eighth- and 74 seventh-grade students) lessons, one to five lessons for each teacher, were used. I used only the first years' lessons for each teacher in order to control for professional development workshops which varied in attendance. The teachers used different textbooks, but the lessons addressed the same mathematical content dealing with variables, equality and equations, and change in algebra (grade 7 and 8) (See Table 2). Three of the textbooks are intended to support teachers in reform-oriented approaches, including the use of student-centered learning and inquiry strategies; the other textbook was a widely used commercial textbook that reflected more traditional instruction. These three textbooks, Connected Mathematics, Math In Context, and Middle School Math Thematics were rated as high, medium, and low satisfactory respectively in the AAAS (2000) textbook evaluation study, whereas Glencoe was rated as unsatisfactory in the same study. From Table 1, two teachers used the textbook *MathThematics* (Billstein, et al., 1999). Fourteen teachers used *Connected Mathematics* (Lappan, et al., 1998). Three teachers used *Glencoe Algebra* (Collins, et al., 1998) and 14 teachers used the textbook *Mathematics in Context (MiC)* (Romberg, et al., 1998).

Table 2

*Learning Goals of the Lessons*


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Content	Description of Content
Variables	Students were asked to recognize both variables and non variables in problem situations, to recognize variable expressions as representations of problem situations, and to recognize that variables can be used to represent a generalized rule or principle.
Equality and Equations	Students were asked to demonstrate understanding of the idea that the equals sign indicates equivalence between two expressions. They were asked to find a set of ordered pairs to solve a simple equation, to recognize the representation of a problem situation with a one variable equation, and to solve simple one-variable equations.
Change	The questions used to assess this group of ideas were mostly conceptual in nature. Students were asked to demonstrate understanding about change in a variable over time, as well as how the change in one variable relates to change in another. They were asked to recognize when the relationship between two variables is linear and the relationship between two variables when represented in the form of an equation.

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### Instrumentation

The Algebra pretest and posttests were developed by the IERI project researchers at the AAAS, University of Delaware and Texas A & M University. The algebra test was designed to measure the knowledge of algebra concepts and skills in variables, change, equality, and equations in middle school students in seventh and eighth grades. The test was specifically designed to evaluate one benchmark from the *Benchmarks for Science Literacy* (AAAS, 1993): symbolic equations can be used to summarize how the quantity of something changes over time or in response to other changes. This benchmark was aligned to *Principles and Standards for School Mathematics* (NCTM, 2000) middle school objective: Use symbolic algebra to represent situations and to solve relationships. There are two forms of the test, each consisting of eighteen items ranging from multiple-choice questions (7), short answer questions (8), and an extended response type question (3). The coefficient alpha reliability of the test was **.81**. The summary information for each of the test items is displayed in Table 3.

Table 3

*Algebra Field Test Categorization*

Item Number	Item Description	Item Type	Content
1	$43 = [] - 28$	Mc	Equality & Equations
2	Represent trading cards $X + 3X = 36$	Mc	Equality & Equations
3	Represent Girl Scouts $N \times 6 = 48$	Mc	Equality & Equations
4	Jacob's rule	Mc	Variables
5	Rule in a table	Mc	Change
6	$Y=2t$	Mc	Change
7	What's true about $Y = 2X + 5$	Mc	Change
8	Tachi and Bill	Scr	Equality & Equations
9	$a=3$ and $b=5$	Scr	Change
10	Small boy raises a flag	Scr	Change
11	Missing number in table	Scr	Change
12	Age of cars	Scr	Change
13	Phone company	Scr	Change
14	Donuts	Scr	Variables
15	$19 = 3 + 4X$	Scr	Equality & Equations

Table 3 continued

Item Number	Item Description	Item Type	Content
16A	Garden Patterns A	Scr	---
16B	B	Scr	Change
16C	C	Scr	Equality & Equations Change
16D	D	Ecr	Change Benchmark

*Note:* Mc = Multiple choice  
 Scr = Short answer question  
 Ecr =Extended response type questions

Measures of the types, quality, and quantity of teachers' questioning were obtained from the analysis of two of the five criteria developed by the IERI project. For this study, the two criteria used were V-A (Encouraging Students to Explain Their Ideas) and V-B (Guiding Interpretation and Reasoning) A computer utility was developed by the project to analyze video tapes of teachers' lessons. The lesson was first analyzed to identify the parts of the lesson that addressed one of the intended algebra learning goals. Next, trained analysts identified and time-coded segments of the lesson (sightings) according to their match with one or more of five criteria (types of questioning). For the identified criterion sighting, the analyst then rated each indicator as met, or partially met, or not met. A measure of the quality of questioning was obtained by first rating each sighting using the indicators. For each indicator, a rating of 1 (Met), 0.5 (Partially Met), or 0 (Not Met) was assigned. The rating of the criterion is obtained by adding the

indicator ratings; thus a criterion rating can range from 0 to 3. The mean of the ratings for a criterion across all sightings for all lessons was calculated to obtain the measure of teacher's quality of questioning for each of the two types of questions.

The quantity of questions was obtained by finding the percentage of minutes of the class used for criteria VA and VB. Some teachers had many small sightings; others have a few larger sightings for a particular criterion, partly depending on the analysts and the teaching approach.

In order to reveal teachers' intentions and reasons for their habits of questioning, interviews were conducted. As Pajares (1992) indicated, it is important to make inferences about an individual's primary states but this is difficult because individuals are not always willing or able to represent their beliefs accurately. Four female algebra teachers were selected whose first year were in the project across the project years. Two teachers were from 2002-2003 and two teachers were from 2003-2004. There were two different types of textbooks, two MathThematics and two Glencoe. The availability of their videos was another reason for the selection of those teachers. The interviews focused on the segments of the lessons in which the teachers asked probing or guiding questions. Short (2-3 minute) video clips/sightings from lessons they had taught were shown. The sightings were those that had been identified by analysts as meeting one or more indicators of the V-A or V-B criteria. After showing the video clip, the following series of questions were asked:

Part I (intention part for 5A)

1. Do you remember this lesson? What was the class doing here?
2. When you asked the questions(s): "..."

Why did you ask that/those question?

3. Which of these reasons was this question supposed to accomplish? (Below part will change according to teacher's intention we suppose like probing or guiding questions)
  - Encourage students *to express* their knowledge or understanding
  - Encourage students *to clarify, justify, interpret, or represent* their knowledge or understanding
  - Provides *opportunities for each student* (rather than just some students) to express their understanding.

#### Part II (Intention of questioning)

1. Do you remember this lesson? What was the class doing here?
2. When you stopped and asked the questions(s): "..."
3. Why did/do you ask that set of questions question?
4. How many of these reasons were your questions or teaching supposed to accomplish?
  - The questions *relate to experiences or learning* with real world examples or representations.
  - The questions *guide students to interpret and reason* about experiences or learning with real world examples or representations.
  - The questions *provide hints or suggestions* to help students to interpret and reason.

#### Part III (habit or skill of questioning)

5. What do you think that How do teachers acquire their habit or skill of

questioning?

The participant interviews were conducted face to face from late October through January. Interviews lasted between 25 and 35 minutes and were audiotaped. After showing teachers short video clips to remind them of the lessons they taught before, teachers were asked questions to understand what they thought about the purpose of asking probing, and guiding questions in their teaching. Later, the indicators of the sightings were shown to the teachers and they were asked how many of them they had intended to accomplish. They were shown two types of indicators: three for probing questions/V-A and three for guiding questions/V-B. Two of the teachers directly indicated the number of indicators they intended to ask. Two of the teachers asked further questions about the indicators and then were able to state the number of indicators they intended to ask.

After completing the intention part interview, the teachers were asked about their acquisition of questioning skills.

### **Data Analysis**

Both quantitative and qualitative analytic methods were used to analyze the video tapes and teachers' interviews. All statistical analyses were correlational in nature and obtained results were attenuated by the reliability of the data; therefore, reliability scores must be reported (Capraro, Capraro, & Henson, 2001; Thompson, 2003; Vacha-Haase, 1998). Therefore, a preliminary analysis was conducted to investigate reliability and validity issues. Issues of validity and reliability of classrooms observations were key for this research. To ensure reliability, graduate students and mathematics specialists were trained to do classroom observations. Using videotapes of teaching, protocols were

followed for video analysis to ensure that analysts applied the coding procedure in standard ways (e.g., the training should include at least three people watching the tape together and then sharing their observations) (Gallagher & Parker, 1995; Schoenfeld, 1992). The data were collected in the different sites where the research was being conducted. Protocols for analysis were developed by the researchers to assure that the same standards were used in the different sites for collection and analysis. Both data and analysis were collected by Project 2061 to be used by the analysis team.

Descriptive statistics, such as frequencies, means and standard deviations, were used to summarize the measures of teachers' quality and quantity of questioning. In this study, covariates are included to adjust for differences. In other words, the covariates are simply used to adjust for variations and compensate for any of those that might affect the true relationship between independent and dependent variables.

For the first research question, Hierarchical Linear Modeling was run with two levels; student and teacher. In student level, dependent variable was students' post-test scores with students' pre-test scores as independent variable. In level 2, teachers' variables; teachers' quality of probing questioning, teachers' quantity of probing questioning, teachers' quality of guiding questioning, teachers' quantity of guiding questioning, teachers' mathematics preparation, teachers' experience, and textbooks were used as independent variables to predict student performance. Since there were some missing information on teacher's mathematics preparation and experience data, I used NORM (Shafer, 1997) to impute data. After I got multiply imputed data, then, I run HLM to conduct multiple analyses for three group data sets separately obtained by imputation. Before running HLM, I made three contrasts for textbooks because it was categorical

variable.

For the second research question, bivariate correlation was used to examine the relationships between teachers' quantity of questioning, quality of questioning, and types of questioning.

For the third question, the teacher interviews were analyzed qualitatively. I applied four interviews to see the diversity of teachers' talk under different categories. First, the teacher interviews were transcribed. I provided thick descriptions for the transferability of the study. Then, the data were considered in terms of their match to the existing categories of probing and guiding (5A and 5B) questions. After transcribing the interviews, teachers' answers were grouped under three categories; remembering the lesson and class, not remembering the class but remembering the lesson, and remembering neither. So, first two categories were found. Teacher's intentions of questioning were analyzed according to their level of match between the teachers' reasons for asking questions and indicators of those two questions types. For triangulation of the data, I asked two types of questions. First, I asked "why did you or what were you expecting by asking those questions" without showing the indicators of the questions they asked. Then, I showed them the indicators of certain question types developed by AAAS and compared the answers from both sources to see if they were parallel. The match of question types or sightings was rated by a second trained researcher on the utility in order to estimate the inter-coder reliability. The inter-coder reliability was .80.



In the third part of the interview, the constant comparison method was used to analyze the data. According to Lincoln and Guba (1985), the constant comparison method was defined by three steps as follows:

1. comparing incidents applicable to each category,
2. integrating categories and their properties,
3. delimiting the theory, and writing the theory (p. 339).

After transcribing the interviews, I detected commonalities and variations among and between them in order to provide individualized care. Later, I categorized teachers' answers of acquiring or learning questioning skill. Finally, I identified common categories that the teachers said they used to learn questioning skills.

## **CHAPTER IV**

### **RESULTS**

This chapter presents the data analysis and addresses the research questions of the study. A mix of quantitative and qualitative analysis was used. Hierarchical Linear Modeling (HLM) was used to investigate the effects of types, quality, and quantity of the teacher questions on students' achievement. Later, the relationship between teachers' quality, quantity, and types of questioning was investigated through bivariate correlation. For the qualitative component, interviews with teachers were used to develop an in-depth look at whether teachers asked what they intended to ask and how teachers believe they acquired their habits and skills of questioning. The four research questions are addressed separately in each of the following sections.

#### **Research Question 1**

What is the effect of the quality of questions, quantity of questions, and types of questions on student achievement? Specifically, how do teachers' types, quantity, and quality of questioning affect students' performance?

Students' pre- and post-test results were used to investigate whether teachers' questioning strategies had any effect on students' post test scores. HLM was applied by creating student and teacher level data sets for the model. In level 1, students' pretest scores were used as the predictor and posttest scores were used as the dependent variable. Level 2 investigated the effects of teachers' experience, teacher mathematics preparation, textbook, quality of probing questioning, quantity of probing questioning, quality of guiding questioning, and quantity of guiding questioning on students' performance (posttest scores). Before running HLM, missing data was imputed by using NORM

(Shafer, 1997) in two steps. First, the mean vector and the co-variance matrix were obtained using the EM (expectation-maximization) algorithm. Second, with the obtained estimates, data augmentation was carried out in order to obtain multiply imputed values to generate three multiply imputed data sets with 99 iterations. Once multiply imputed data sets were obtained, HLM was conducted to analyze each separately. Finally, the means of three parameter estimates for each predictor variable were calculated to address both research questions 1 and 2.

In order to run HLM for these data sets, all variables should have been interval variables. Since textbooks were categorical variables, three contrasts were set for four textbooks comparing higher versus lower rankings. CMP and MiC are the higher ranked and MathThematics and Glencoe are the lower ranked according to AAAS (2000) research. The first contrast compared the average of CMP and MiC (higher ranked) with the average of MathThematics and Glencoe (lower ranked); the second contrast compared CMP with MiC, and the third contrast compared MathThematics with Glencoe.

After running HLM with imputed data sets 1, 2, and 3, the intercorrelations shown in Tables 4, 5, and 6 were obtained between groups.

Table 4

*Estimated Sample Statistics for Between: Correlations for Imputed Data 1*


---

	Postot	Pretot	Tprep	Texp	Faql	Faqn	Fbql	Fbqn	C1	C2	C3
Postot	1.00										
Pretot	0.00	0.00									
Tprep	0.26	0.00	1.00								
Texp	0.45*	0.00	0.23	1.00							
Faql	0.17	0.00	-0.09	0.18	1.00						
Faqn	0.21	0.00	-0.23	0.45*	0.10	1.00					
Fbql	0.02	0.00	0.12	0.37*	0.24	0.14	1.00				
Fbqn	0.38*	0.00	0.19	0.91*	0.21	0.48	0.31	1.00			
C1	0.43*	0.00	-0.20	0.14	-0.24	0.35	-0.25	-0.02	1.00		
C2	0.19	0.00	-0.01	0.20	-0.42	0.10	-0.10	0.00	0.30	1.00	
C3	-0.03	0.00	-0.19	-0.09	0.17	-0.04	-0.02	-0.17	-0.03	-0.01	1.00

---

Tprep= teachers' mathematics preparation

Texp= number of years of teaching experience

Faql= quality of guiding question, Faqn= quantity of guiding questions, Fbql= quality of probing questions, Fbqn= quantity of probing questions

Table 5

*Estimated Sample Statistics for Between: Correlations for Imputed Data 2*

	Postot	Pretot	Tprep	Texp	Faql	Faqn	Fbql	Fbqn	C1	C2	C3
Postot	1.00										
Pretot	0.00	0.00									
Tprep	0.25	0.00	1.00								
Texp	0.45*	0.00	0.26	1.00							
Faql	0.09	0.00	-0.09	0.19	1.00						
Faqn	0.26	0.00	-0.22	0.43*	0.09	1.00					
Fbql	0.08	0.00	0.13	0.39*	0.21	0.14	1.00				
Fbqn	0.36*	0.00	0.21	0.89*	0.21	0.49	0.31	1.00			
C1	0.52*	0.00	-0.19	0.14	-0.23	0.38	-0.23	-0.02	1.00		
C2	0.26	0.00	-0.01	0.21	-0.40	0.13	-0.07	0.01	0.30	1.00	
C3	-0.06	0.00	-0.20	-0.09	0.16	-0.05	-0.03	-0.18	-0.03	-0.01	1.00

Tprep= teachers' mathematics preparation

Texp= number of years of teaching experience

Faql= quality of guiding question, Faqn= quantity of guiding questions, Fbql= quality of probing questions, Fbqn= quantity of probing questions

Table 6  
*Estimated Sample Statistics for Between: Correlations for Imputed Data 2*

	Posttot	Pretot	Tprep	Texp	Faql	Faqn	Fbql	Fbqn	C1	C2	C3
Posttot	1.00										
Pretot	0.00	0.00									
Tprep	0.17	0.00	1.00								
Texp	0.34*	0.00	0.24	1.00							
Faql	0.15	0.00	-0.11	0.18	1.00						
Faqn	0.25	0.00	-0.22	0.45*	0.06	1.00					
Fbql	0.06	0.00	0.12	0.38*	0.20	0.14	1.00				
Fbqn	0.31*	0.00	0.23	0.91*	0.19	0.48	0.32	1.00			
C1	0.40*	0.00	-0.19	0.14	-0.26	0.39	-0.21	-0.01	1.00		
C2	0.26	0.00	-0.01	0.20	-0.42	0.14	0.05	0.02	0.30	1.00	
C3	-0.07	0.00	-0.23	-0.07	0.17	-0.04	-0.03	-0.18	-0.03	-0.01	1.00

Tprep= teachers' mathematics preparation

Texp= number of years of teaching experience

Faql= quality of guiding question, Faqn= quantity of guiding questions, Fbql= quality of probing questions, Fbqn= quantity of probing questions

As shown in Tables 4, 5, and 6, posttest scores were positively significantly correlated with teachers' experience ( $r=.40$ ,  $p<.05$ ). Teachers' experience also correlated significantly with the quantity of probing questions ( $r=.45$ ,  $p < .05$ ) and quality ( $r= .38$ ,

Table 7

*Model Results*

	(Est. /S.E)-1	(Est. /S.E)-2	(Est. /S.E)-3	Average
<u>Within Level</u>				
Posttot on				
Pretot	13.921*	12.939*	14.208*	13.689*
<u>Between Level</u>				
Posttot on				
Tprep	2.112*	2.124*	1.746	1.994*
Texp	-0.824	-1.091	-1.775	-1.230
Faql	2.277*	1.899	2.654*	2.276*
Faqn	-0.816	-0.834	-0.556	-.735
Fbql	0.184	0.862	0.697	.581
Fbqn	1.507	1.606	1.913	1.675
C1	4.084*	5.058*	3.743*	4.295*
C2	1.279	1.585	2.134*	1.666
C3	0.478	0.410	0.349	.412

\*  $p < 0.05$ 

Tprep= teachers' mathematics preparation

Texp= number of years of teaching experience

Faql= quality of guiding question, Faqn= quantity of guiding questions, Fbql= quality of probing questions, Fbqn= quantity of probing questions

$p < .05$ ) and quantity ( $r = .91$ ,  $p < .05$ ) of guiding questions. Other interesting findings were that textbook rating and quantity of guiding questions were positively correlated with posttest scores ( $r = .45$  and  $r = .35$ ,  $p < .05$ ), respectively. These results were similar with all three imputed data sets as shown in Tables 4, 5, and 6.

For the analysis of the model results, the alpha level was set to 0.05 with 1.96 critical values for normal t-statistics meaning that a t-test value greater than 1.96 is significant. Even though there were significant correlations between teachers' experience, quantity of teachers' probing and guiding questions and students' test scores, the effects of these variables changed in the analysis.

As illustrated in Table 7, pretest scores predicted post test scores with a significant average t value of 13.689 ( $p < .05$ ). The effect of teacher mathematics preparation was significant ( $t = 1.994$ ,  $p < .05$ ), which means that the number of math courses teachers took predicted students' achievement. The quality of teachers' probing questions significantly predicted students' performance ( $t = 2.276$ ,  $p < .05$ ), indicating that higher quality probing questions resulted in higher student test performance when other variables were controlled. Contrast C1 had a significant effect ( $t = 4.295$ ,  $p < .05$ ), which means that higher rated textbooks predicted students' performance positively as found by Kulm and Capraro (2004).



Table 8

*Tests of Model Fit for Imputed Data 1, 2, and 3*

	1	2	3	Average
P value	0.00	0.00	0.00	0.00
Chi-square	486.29	453.54	490.04	476.62
RMSEA	0.00	0.00	0.00	0.00
Df	10	10	10	10

Mplus analysis produced the sample correlations and the chi-square test of the model for the sample data. As seen in the results in Table 8, the chi-square test was statistically significant, so the null hypothesis says that the factor fit the data is rejected; more factors are required to obtain a non-significant chi-square. Since the chi-square test is sensitive to sample size (such that large samples often return statistically significant chi-square values) and non-normality in the input variables. Mplus also provides the *Root Mean Square Error of Approximation (RMSEA)* statistic. The RMSEA is not as sensitive to large sample sizes. According to Hu and Bentler (1999), RMSEA values below .06 indicate satisfactory model fit. Mplus displays the sample statistics for each group separately. From Table 8, it is seen that the obtained chi-square model fit statistic (476.62) is larger than its degrees of freedom (10). But the RMSEA is well below the cutoff value of .06, leading to the conclusion that the model fits the data very well.

### **Research Question 2**

What is the relationship between the quality of questions, quantity of questions,

and types of questions?

This question was investigated by computing inter-correlations between the variables. Since there were no pre-assumptions about the relationship between quality, types, and quantity of questioning, a 2-tailed test was accepted for significance level.

As shown in Table 9, it was found that quality and quantity of guiding questions and probing questions were significantly correlated with each other. The quality of probing question was negatively correlated with the quantity of probing questions, indicating that the higher the quality of probing questions is, the shorter the length of class time the teachers used with probing questions. Moreover, teachers' quality of probing questions was positively correlated to the quality and quantity of guiding questions. So, it can be said that the quality of teachers' probing questions was associated with using higher quality and more class time on guiding questions.

There was a positive significant relationship between the quantity of probing questions and quality and quantity of guiding questions. Finally, there was a positive significant relationship between the quality of guiding questions and the quantity of guiding questions.

Table 9

*The Relationships Between Quality, Quantity, and Types of Teachers Questioning:**Correlations for Imputed Data 1, 2, and 3*

				Average				
				-----				
	Faql	Faqn	Fbql	Fbqn	Faql	Faqn	Fbql	Fbqn
-----								
	1	-.059**	.376**	.152**				
Faql	1	-.066**	.365**	.148**	1	-.069**	.365**	.146**
	1	-.082**	.355**	.137**				
	-.059**	1	.138**	.355**				
Faqn	-.066**	1	.137**	.355**	-.069**	1	.138**	.355**
	-.082**	1	.140**	.354**				
	.376**	.138**	1	.387**				
Fbql	.365**	.137**	1	.387**	.365**	.138**	1	.386**
	.355**	.140**	1	.385**				
	.152**	.355**	.387**	1				
Fbqn	.148**	.355**	.387**	1	.146**	.355**	.386**	1
	.137**	.354**	.385**	1				

\*\*=Correlation is significant at the 0.01 level (2-tailed).

Faql= quality of guiding question, Faqn= quantity of guiding questions, Fbql= quality of probing questions, Fbqn= quantity of probing questions

### Research Question 3

Do teachers ask the questions they intend to ask?

Two approaches could be used to determine if the teachers were aware of what they were asking. The first approach would be to examine the teachers' questions and compare them with students' answers. If they correlated with each other, then, one could say that teachers asked what they wanted to ask. However, because in these videos only the teacher had a microphone, the students' answers were often difficult to hear. Therefore, this method of analysis was not possible. The second approach was to compare the indicators of the types of teachers' questions with the teachers' explanations of asking those questions. The latter was used to investigate teachers' intentions in asking questions.

#### *Teacher Interviews*

The interviews were conducted face to face with the four teachers from late October through January. Each interview lasted between 25 and 35 minutes and was audiotaped. Since the lessons chosen for this study has been videotaped between 2002 and 2005, there was a considerable time lag between the time the lesson was taught and the time the interview was conducted. Therefore, the short video clips were crucial and effective in reminding teachers of their perceptions of their teaching and intentions. Table 10 summarizes the extent to which each teacher was able to recall the lessons from the video clips.

Table 10

*The Teachers' Answers About Remembering the Lessons They Taught*

Teachers	Guiding Questions		Probing Questions	
	Remembered both	Remembered content but not the lesson	Remembered both	Remembered content but not the lesson
Ms. L	x		x	
Ms. S		x		x
Ms. M	x		x	
Ms. D		x	x	

As shown in Table 10, eight short video clips were shown to the four teachers. Each teacher watched two video clips; one for each question type. Two teachers did not remember the actual lesson but remembered the content they taught. Three teachers remembered both the actual lesson and content and were able to explain why they asked specific questions after watching the video clips.

In order to provide information on the variations in the way teachers remembered the lessons, content, and questions, the following examples are offered. Three examples of teachers' responses are discussed.

Ms. L's answers showed that the short video clips were very helpful to her in

remembering specific information about the lessons. The lessons shown her were from 2003-2004.

I: Do you remember the lesson? What was the class doing here?

Ms. L: Yes. I was kind of guiding him through it. Basically, this is the thing we talked about the year before he was in my class. I did not have him in 7<sup>th</sup> grade. Normally, I teach 6<sup>th</sup>, 7<sup>th</sup> grade and pre-algebra and the other teacher teaches 8<sup>th</sup> grade. That year, I just took 7<sup>th</sup> and 8<sup>th</sup> grade as well. So, it was my first year to teach them. Prior to my teaching them, they really lost some of the concepts. Maybe, they just really passed through really fast and he did not learn it well. I pretty much guided him through, this is x, this is y.

Ms. S remembered the content of the lesson by watching the video clip but not the specific lesson she taught. In other words, she did not remember the class she taught but she remembered the content she taught. The video clips shown her were from 2003-2004.

I: *Do you remember this lesson? What was the class doing here?*

Ms. S: I think we were adding and subtracting integers. I think that is what it was. Actually, I don't remember I was doing that but once I see that I remember teaching that way.

I: *Do you remember which class was that, number, algebra?*

Ms. S: It was straight math class.

Immediately after watching the video clip, Ms. D remembered neither the content nor the class she had taught. Later, she figured out her own way to remember what she was teaching by looking at the textbook she used for that lesson. The video clips

shown her were from 2002-2003.

I: *Do you remember this lesson? What was the class doing here?*

Ms. D: Not really, I wish I had the lessons in front of me. This was four years ago. I can't really recall exactly. (She fetched the textbook and found the lesson and she was reminded what she was doing from the textbook). These are the questions. They were, looks like, drawing and interpreting histograms.

These examples illustrate how the video clips helped in obtaining reliable data. Even though these lessons were three to four years old, the teachers could still remember the content they taught. In most cases, the teachers were able to recall specific information about students and the lesson.

### *Teachers' Intentions*

In the lessons, the four teachers were usually a facilitator of whole class discussions. In other cases, teachers provided help to individual students during in-class practice work. The content of the four lessons was about change, variables and equations. Teacher's intentions of questioning were analyzed according to the level of match between the teachers' reasons for asking questions and indicators of those two questions types. For triangulation of the data, the teachers were asked two types of questions. First, without showing the indicators of the questions, they were asked "Why did you ask '*why or how*' or *probing or guiding* questions?" They were next shown the indicators of probing and guiding questions and asked to choose one or more of the indicators that best matched their intention. In the following analysis, the responses to both of these parts of the interview were compared to determine if they were parallel.

### *Probing Questions*

The four teachers' answers to the interviews were very similar. They all provided similar responses for asking 'how' and 'why' questions. They also chose indicators for probing questions that matched their stated intentions. The following excerpts from two of the teachers' interviews are provided to illustrate these similarities.

#### *Lesson Description: Ms. L*

The video clip shown to Ms. L was a class interaction in which she was asking the students for the values of variables on the table of input, rule, and output as the review of the previous day's lesson. The goal of the lesson was to get them ready to draw the graph of the function. Later, she asked them "What do you think are we going to do now?" As soon as she got the answer of "graph", she asked "How can I graph this table?" Then, she asked "What do I need to make this table to graph?" Some students said that they needed to pick numbers. Ms. L asked what kind of numbers you need to pick. Finally, they picked numbers for each axis. Ms. L asked them "How do I know where to put my points?" She pushed students to recall their previous knowledge. One of the students said that we need to make ordered pairs. Ms. L asks the students "How do I make my ordered pairs? What is the ordered pair? How can I get ordered pairs from the table?" Finally, one of the students said that we take one from the input and one from the output and they started drawing the graph of the function.

#### *Interview: Ms. L*

I:        *When you asked the questions: Why do you say that? How can I take this to the graph? How can I graph? How do I make ordered pairs from this table? Why did you ask 'Why and How' questions?*



Ms. L: A big part of the math in junior high level is making kids explain what they do. A lot of times they'll tell something in my classes and I want to know how they got it. If I ask them "why is that?" a lot of times, kids don't know where to go. So, I usually start with *how* questions so they can explain what they did first and then I can lead them into *why* questions to make them explain a little more in detail.

I: *Now, I am going to show you some indicators or reasons and I want you to pick if they are applicable to your situation: How many of these reasons were your questions or teaching supposed to accomplish?*

- Encourage students *to express* their knowledge or understanding
- Encourage students *to clarify, justify, interpret, or represent* their knowledge or understanding
- Provides *opportunities for each student* (rather than just some students) to express their understanding.

Ms. L: I will say pretty much all of them because I am always asking them like as I said before "tell me what are you doing" and how did you do that?" So, you know, checking on their knowledge and what they are really understanding. And then, some of the "how" questions may be have them okay, they may tell me something. But to really test their understanding, I have them clarify or explain even further into their understanding. You know, it says, justify it or interpret what they did. Especially with the graphing, it says providing opportunities for each student to express their understanding; you may see or may not see in that video but the class was only six people total. So, with only six kids, you know if

you had a bigger class, sure there is a lot more kids asking questions but whenever you have a small group like that I try to give every kid a chance. Some kids if they aren't getting it, some of the others who do explain it and they listen to them just as much as they listen to me. So, if, at least, I had two or three explaining it, that would be good considering only six in the class.

*Lesson Description: Ms. S*

The video shown to Ms. S was a class discussion in which she was talking about how to solve one step equations. She was using tiles to solve the equations given them. She was demonstrating step by step with them since each student had the same manipulatives. One of the examples she was solving was  $x+1=6$ . She started asking Okay, we are going to add 6. "So, what color am I going to use?" X is equal to positive six so, "What color am I going to use?" The students said that the color is yellow. She said that "let's put six yellows." She said, "On the other we took three of this side and three of the other side, what am I going to do this time?" Students say one of each side. She then asked, "Why do I have to do both sides?" One of the students answered, "Because whatever you do to one side you have to do to the other side." She reworded the student's answer and said: What I do to the one side I do to the other side. She continued by saying one off here and one off here. What am I left with? Some students said "5." She said, "Then, x equals five."

*Interview: Ms. S*

I:        *When you asked the questions: "Why do I have to do to both sides? Why?"*  
             *What response were you expecting? Why did you ask 'why' types of questions?*

Ms. S: I guess I was trying to get them to think about what we were doing and read them in their mind. I know a lot of times they don't understand like why you have to do both sides. They don't realize you have to go both sides because you can't do one thing one side and not do the other side you know what I mean. So, when I asked why questions I wanted them to think why I am doing this instead of saying *this is what you have to do*, you know. So, I wanted them to think about why we are doing this.

I: *How many of these reasons were your questions or teaching supposed to accomplish?*

- Encourage students *to express* their knowledge or understanding
- Encourage students *to clarify, justify, interpret, or represent* their knowledge or understanding
- Provides *opportunities for each student* (rather than just some students) to express their understanding.

Ms. S: I think each student did not get to express but you know pretty much first two definitely. On the third one, I mean opportunity part. You know, it was kind of call out for answer and I know some students were sitting there and watching it. So, first two I think.

Table 8 shows the relationship of the four teachers' responses for the probing questions. Even though they were not shown the indicators, the teachers' answers to the first questions about the reasons for asking *why* and *how* questions were very similar to and their choice of indicators.

Table 11

*Comparisons of Teachers' Answers to Question 2 and Question 3*


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	Question 2	Question 3
Teachers	Why did you ask  “why and/or how” questions?	<i>How many of these reasons were</i>  your questions supposed to accomplish?
Ms. L	She asked <i>how</i> questions to let them explain.  She asked <i>why</i> questions to make them explain little more.	All three
Ms. S	She asked <i>why</i> questions to let them think what they were  doing and to read their mind.	1, 2,
Ms. M	She asked <i>why</i> questions to let them articulate what they  are thinking. She believes that being able to articulate is a  key to learning.	1, 2
Ms. D	She asked <i>why</i> and <i>how</i> questions to make them explain  if two things are similar or different  She used probing questions to make them analyze the topic  being discussed.	All three

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As summarized in Table 11, teachers' purposes of asking probing questions were mostly similar. Ms. L discussed the difference between asking *how* and *why* questions. According to her, students were usually panicked when they were asked *why* questions. Therefore, it was better to start with a *how* question. Then, teachers should continue with *why* questions to receive more explanations or thought from students. So, as in the indicators, *how* questions were more related to first indicator of probing which was to *encourage students to express their knowledge or understanding*. *Why* questions were more similar to the second indicator which *encourages students to clarify, justify, interpret, or represent their knowledge or understanding*.

Ms. S said that she focused on her students' minds or thinking processes. By asking *why* questions, she intended to see their thought processes in an effort to understand what they were doing. In other words, she mostly focused on their ability to explain and justify what they were doing, as in the second indicator. Also, she said that she knew there were some students only sitting and watching. Therefore, the first two indicators were what she was trying to accomplish with *why* questions.

Ms. M wanted to see if her student were able to express and elaborate their thinking as in the first and second indicators. She said that if they can articulate, then, they can understand what they were discussing. So, articulation was the key to the learning according to her. Her only concern was that although most of her students followed her thinking, she could not reach all of them through oral discussion. Therefore, she could not carry out her intention completely. Thus, she said only the first two indicators were performed.

Ms. D also used *why* and *how* questions in her teaching. She intended to have students articulate their thinking. She focused on whether they could analyze the topic being discussed by explaining the differences and similarities in the concepts being taught. Ms. D also believed that she accomplished the third indicator by giving a chance to each student in her classroom.

### *Guiding Questions*

For the guiding questions, all four teachers gave similar responses for the reasons they asked this type of question. The four teachers chose all three indicators, believing that they met all the requirements for guiding questions.

The following excerpts from two of the teachers' interviews are provided to show their detailed answers to both questions. The first one was chosen because at the beginning, where Ms. S was not sure if she understood the question correctly. With some help from the interviewer, she realized that she intended to ask all three indicators. Her answers to both questions were consistent and similar. In the second one, Ms. D said that the students in the clip were stuck and needed help. That was why she asked the set of questions in the episode.

### *Lesson Description: Ms. S*

Students were solving equations from a worksheet while Ms. S was walking around the classroom, checking if students had any problems with understanding the topic being discussed. One of the students had a question whether she needed to add or subtract. Ms. S asked the student "this is what sign?" The student said, "Plus." She kept asking "opposite of adding?" The student said, "Subtraction." The teachers approved her answer by saying "yes." Then, the student said, "So, I need to add these two." Ms. S said

“No.” and added “You needed to do like this: Negative three plus five.” Later she asked, “What is the opposite of adding five?” The students said, “Subtract.” So, Ms. S said, “minus five.” Then, “Negative ten stays the same when you subtract five from each side.” She asked, “What is negative ten plus negative five?” The student said, “Fifteen.” She asked, “Positive fifteen or negative fifteen?” The student said, “Positive.” She said, “You are adding two negatives.” The student said, “Oh negative.” She said, “Now what?” The student said, “T is equal to negative fifteen.” She said, “No,” and added, “We need to divide by negative three because T has to be all by itself and negative divided by negative?” The student said, “Positive.” She asked, “What about “fifteen divided by three?” The student said, “Five.” She said, “That is all.”

*Interview: Ms. S*

I: *Do you remember this lesson? What was the class doing here?*

Ms. S: From the overhead projectors, I guess, it was about solving equations.

I: *When you asked the questions: “.....What is opposite of adding? What is negative ten plus negative five?... What? ... Negative fifteen or positive fifteen?..... Why did you ask those kind of or set of questions?*

Ms. S: I don't remember that student whether she was stuck or did not understand the lesson you know but my guess would be that I was giving some points or clues. It seems I solved pretty much whole problem for her. Maybe just having them refresh on how to work problem out I guess what I was doing there.

I: *How many of these reasons were your questions or teaching supposed to accomplish?*

- The questions *relate to experiences or learning* with real world examples or representations.
- The questions *guide students to interpret and reason* about experiences or learning with real world examples or representations.
- The questions *provide hints or suggestions* to help students to interpret and reason.

Ms. S: There weren't really any real world examples on there so I guess only the last one "provide hints..."

*I: It does not have to be both. What about the representations?*

Ms. S: Ok. Then, it would be the second one, too. I mean I pretty much walked through whole episode and used questions. So, I think both second and third. Well, I don't know obviously if I was giving a quiz we have been learning about that for a while also. I guess one too even though there weren't real world examples we were going back to what we had already previously learned from integers to the one step equations, two step equations. So, I guess, the first one would maybe fall under that too.

*Lesson Description: Ms. D*

Ms. D was helping her students individually by asking set of questions based on their requests. She stopped one by one and led them to convergent thinking with other students. She stopped at one of the students' desk upon request and said, "You were working on number ten, right?" And "Show me how you got these?" The student showed something and was not sure if she was doing it right. Then Ms. D said, "You have seven



and why do you think it is eight?” The student said, “Because I didn’t know how to get it.” Ms. D asked, “Do you know where the tally marks came from?” Ms. D explained to her where the tally marks came from by saying, “There are numbers between five and seven. So, how many numbers are there between them?” The student said, “Oh I see. There are three.”

*Interview: Ms. D*

I: *When you stopped and asked the questions: “how many...? Why do you think..? Which one? How many?” Why did/do you ask those set of questions question?*

Ms. D: They were given this information and obviously, they did not know what to do with this information. They did not understand where the one and three came from. So, by showing them how and where the one and three came from and hoping that they could figure out how to complete their chart. So, I asked questions to prompt them. What do you know what the tally marks stand for?

I: *How many of these reasons were your questions or teaching supposed to accomplish?*

- The questions *relate to experiences or learning* with real world examples or representations.
- The questions *guide students to interpret and reason* about experiences or learning with real world examples or representations.
- The questions *provide hints or suggestions* to help students to interpret and reason.

Ms. D: In this specific situation, I was not relating to experiences with real world

examples because we were solving this particular case but we did representations. Yes, I was trying to scaffold that learning. Pretty much all of them.

For the guiding questions, all four teachers' answers were intended to ask to guide or help to the students and they were aware of the role of questions they asked.

Table 9 shows the relationships of the four teachers' responses for the guiding questions. The reasons provided for asking guiding questions varied from helping students to recall needed information to providing specific hints or clues in completing a problem. All four teachers believed they met all three indicators for guiding questions.

From Table 12, it is seen that Ms. L was trying to guide her students because they were stuck. In other words, she was re-teaching the content in order for her students to catch other students in the classroom as in indicator two for guiding questions:

The kid I was helping really had trouble understanding  $x$  and  $y$ , the whole year and so I was trying to help him. You probably heard me saying more because it was hard to hear the kid, but he gets confused that is what most junior high students do. They either really get  $x$  and  $y$ , where they are, how to move when you do all four quadrants. In sixth grade, they only do the first quadrant. So, in 7<sup>th</sup> and 8<sup>th</sup> grade, they start doing all four quadrants. So, it gets confusing and they always mixed up which way to move first or which one is  $x$  and  $y$ . So, walking through step by step for the first one to reinforce them otherwise they would do nothing.

Table 12

*Comparisons of Teachers' Answers to Question 2 and Question 3*

	Question 2	Question 3
Teachers	Why did you ask those set of questions?	<i>How many of these reasons were your questions supposed to accomplish?</i>
Ms. L	She was trying to guide him by re-teaching the  topic because students were stuck.	All three
Ms. S	She was giving some points or clues to refresh  his knowledge.	All three
Ms. M	She was instructing and teaching them in order to them  to recall necessary knowledge.	All three
Ms. D	She was helping them to figure out how to do the problem  being discussed.	All three

Then, she gave suggestions step by step to help her students to able to interpret the problem as in the third indicator. Therefore, she said that she asked those guiding questions to push them to do something for the problem even though she did not relate her teaching to the real world parts:

We were not really doing the real world part yet that day but it was coming on the next day. The basic thing I was doing was both bottom two: ...*guiding students to interpret and reason* about experiences or learning not necessarily the real world examples but the representations part because they had to that master first before the next lesson which was about real world examples and also providing *hints or suggestions* to kind of help them refresh their memory to re-teach them as well. The guiding question were they can give me a simple one word response or they were not pressed for big explanation to they might be feeling that they were lost and not knowing what they were talking about. So, I would say that one is too because the next was going to be on real world.

Ms. S tried to give some points to help her student even though she was not sure if her student was stuck (Table 12). She said that she tried to remind them what they studied before by asking set of questions as following:

I don't remember that student whether she was stuck or did not understand the lesson you know but my guess would be that I was giving some points or clues. It seems I solved pretty much the whole problem for her. Maybe just having them refresh on how to work problem out I guess what I was doing there.

She said that she intended to accomplish all three indicators with my guiding questions:

Ms. S: There weren't really any real world examples on there so I guess only the last one "provide hints..."

I: *It does not have be both what about the representations?*

Ms. S: Ok. Then, it would be the second one, too. I mean I pretty much walked through

whole episode and used questions. So, (I pick) second and third but not the third one. well, I don't know obviously if I was given a quiz we have been learning a about that for a while also. I guess one too even though there weren't real world examples we were going back to what we had already previously learned from integers to the one step equations, two step equations. So, I guess, the first one would maybe fall under that too.

Ms. M said that the lesson she taught them was a review part of the topic being discussed. She intended to teach them the lesson because they were missing some basic information in order to move forward. Therefore, she tried to guide them to the convergent thinking with others in the classroom:

We were reviewing integers and so the point was that I was instructing and teaching them. But they needed to recognize specific things in order to take those words into account. That was what I was looking for. Could they identify the thing they already learned? I was trying to get them recall those. They had already done it but they were seen it in slightly different way and so they were relating the things they knew with this new situation. So, you know, I used the same kind of things we talked about when we did it in this situation and in new situation. Just kind of guide them to see that what knew applied in this situation. So, in the clip, she was not confident with what she was doing. So, I want to make sure that, you know sometimes students get stuck. You don't want to direct them or teach it again. This was a review. So, you just want to keep them moving forward.

For the indicators, she picked the third and the second indicators first because she said that she was trying to guide them by giving some hints:

The certainly the third; the first one is certainly that is where they were having difficulties relating something they have already done to a representation. I mean that is where they weren't feeling confident. *Guide them to...* I think you can round to it. But my question was to give them hints and suggestions not to re-teach it.

Later, she said that even though the first indicator or relating *to experiences or learning with real world examples or representations* was the difficult one for them, she aimed to accomplish by asking guiding questions:

They were supposed to be relating it. So, I needed them to do it and do it correctly and feel confident that they can do it. And some of them obviously were not super confident so, one of them needed guidance and some of them just needed support. She was doing it but she surely was not confident about it.

Ms. D said that she tried to facilitate their learning by asking a set of questions. She helped them by showing where the numbers were coming from as shown below.

They were given this information and obviously, they did not know what to do with this information. They did not understand where the one and three came from. So, by showing them how and where the one and three came from and hoping that they could figure out how to complete their chart. So, I asked questions to prompt them. What do you know what the tally marks stand for?

For the indicators, she said that even though she did not or aimed at talking about real world examples; she was teaching and using representations. So, she believed that

she accomplished all three indicators:

In this specific situation, I was not relating to experiences with real world examples because we were solving this particular case but we did representations. Yes, I was trying to scaffold that learning. Pretty much all of them.

#### **Research Question 4**

How do teachers' acquire their habit or skill of questioning?

In attempting to determine how teachers acquired their habits and skills of asking questions, they were asked two types of questions. First, they were asked directly how they had acquired the habit or skill of questioning and how they developed their questioning skills. Then they were asked if they learned questioning on their own or if it is taught in college. As summarized in Table 10, several methods seemed to be the most frequently used to learn questioning methods.

Table 13

*Teachers' Answers to Acquire Questioning Habit or Skill*

Teachers	How do teachers acquire their habit or skill of questioning?	How did you develop your questioning skill?	Did you learn it during college years?
Ms. L	Depends on types of teachers: For ex: Local teachers tend to ask more? Trainings, workshops, Meeting with different people Watching other teachers Watching your videos Depends on the kids in your classroom	From different trainings Field experience Being with real teachers Lectures from college Real life exposure with kids	Yes and No
Ms. S.	Watching other teachers' teaching	From middle and high school teachers	No
Ms. M.	Watching good teacher Observing teachers Field observations Working with teachers	Teachers from student teaching Discussing with teachers Field experience Personality Workshop (MSMP*)	No
Ms. D	Personality Textbook	Teachers from student teaching Watching supervisor teacher	Yes

\* MSMP=Middle School Mathematics Project



Ms L. discussed many different methods for learning questioning skills. She also explained how she acquired her questioning skills. She said that college partially helped her learn questioning.

I: *How do teachers acquire their habit of questioning?*

Ms. L: Oh, that is a good one. Acquiring habit of questioning, well, one, it depends what type of teacher you are. If you are a very vocal teacher that is not afraid of asking questions, or not to be afraid of your students if they ask questions that you may not be able to answer and to be able to know where to go with that. A lots of training, different trainings, when you go to different workshops, you meet different people, hear different peoples' speak, experience different types of things, hands on or you may be the student yourself. All those types of things and so you end up with hearing other peoples' questions or you may see video clips of other classes and see what works for them. Also, you may watch your own videotaping to where you can reflect on yourself and see what would have been a better question to ask at that moment instead of what you did already. So, there are a lot of different things and some of those could stem from the kids in your classroom.

I: *Was it something you learned during college years? How did you develop your questioning skill?*

Ms. L: Yes and no. I would say in the fact that from the different trainings. When an undergraduate, I was an undergraduate a long time ago and things changed a lot now and I think it is much better now. But when I was an undergraduate, the time in the classroom, the classroom experience, going out in the field, being in

the classroom with the actual teachers and helping them out, seeing how they are doing it. You pick up things and you get exposed to different strategies in the classroom. So, I think, having the exposure in the classrooms is very beneficial because you be taught a lot with lecture at A&M or at any college but real life exposure out in the classrooms with real kids, what kind of questions kids are asking and how they are responding the questions, I think, is very helpful.

On the other hand, Ms. M claimed that there was no institution or course you can benefit from in order to acquire questioning skill. She believed that observing and watching good teachers was the key to develop questioning skill. Moreover, she said that personality was also something affecting teachers' questioning skill.

I: *How do teachers acquire their habit of questioning?*

Ms. M: There is no institution or course you can go or take and learn how to ask questions. I think that most teachers if they had gone through traditional teaching education do a lot of observing teachers, field observations and experiences. That is the beginning place. If you are fortunate to have people who are good at it and can explain why they do it. I think that a lot of teachers don't to have opportunity, they do have the opportunity, I mean, good questioner has the opportunity to sit in the classroom and watch the teacher do that and ask why they do that. So, once you understand why you are trying to question, then you make the questions better. This program (MSMP) was the only program I have ever been had a specific goal of teaching how to ask questions better.

I: *Do colleges teach how to ask questioning? How did you develop your questioning skill?*

Ms. M: No. I was very fortunate to be, and I don't know if I am a great questioner but it works for me, for my personality. My kids tend to do well. But I think watching good teachers are really the key to finding out, you know, happen to ability to watch them and to discuss that. That is really opportunity to watch them and field experiences. So, to me, that is the place where they acquire and learn how to do that.

I: *Do you think that personality has something to do with questioning?*

Ms. M: Oh yes, I have seen no equally if not more effective teachers with a; they might ask differently. I do a lot of, you know, "what? Why? Explain to me?" The kind of questions does not differ but the presentation of that, you know, the way they ask may change.

From all four teachers' interview episodes, teachers agreed on several things. First, questioning skill was not something taught in college specifically. Second, the most often used strategies were acquired watching or observing good teachers, being in the field or from student-teacher experience, and workshops. Finally, other methods mentioned were as follows; personality, textbook, and lectures from college. So, each teacher acquired questioning techniques in different situations and not mostly in systematic ways.

## CHAPTER V

### DISCUSSION AND CONCLUSIONS

This study is divided into two parts. In the first part, the effects of teachers' quality, quantity, and types of questioning method on students' performance were investigated when teachers' teaching experience, teachers' mathematics preparation knowledge, and textbooks were taken into consideration. In the second part, due to the importance of teachers' questioning skill in mathematics education, teachers' intentions of asking probing and guiding questions and teachers' acquisition of questioning skill were examined through face-to-face interviews.

In the first part, the effects of teachers' quality and quantity of probing and guiding questioning on students' posttest scores were investigated by using HLM. Bivariate correlations were then applied to determine if there is a relationship between teachers' quantity, quality, and types of questioning. In the second part for the first question, teachers' awareness of use of probing and guiding questions were studied by matching teachers' sayings for asking those types of questions and the indicators of those two types of questionings. For the second question, four algebra teachers were asked about how they acquired their habit of questioning methods.

This chapter discusses the major findings of this study addressed in the results part.

#### **Teachers with More Preparation, Better Textbook and Quality Probing Questions**

HLM results and inter-correlations produced a positive significant correlation between students' post test scores and teachers' experience. This could indicate that the

student with more experienced teachers got better assignments. Moreover, this could be reason because teachers with more years of experience may have more knowledge and better classroom management. As a result, the students of experienced teachers may get higher scores on tests. Also, teachers' experience had significant relationships to the quantity of probing questions and quality and quantity of guiding questions. So, it can be said that teachers with a greater number of years of teaching ask more probing questions. Moreover, teachers with higher years of teaching experience may guide and help students more than teachers with less years of teaching. Experienced teachers may have had more opportunity to see what kinds of questions were more effective. What is more, they may know when students need guidance and open-ended question. Thus, they may ask more probing questions and more and better guiding questions in need. Furthermore, intercorrelations from HLM analysis showed that students with higher rated textbooks, CMP and MIC, do better job than lower rated textbooks, Glencoe and MathThematics. This may be stemmed from the quality of higher rated textbooks. CMP and MIC may have comprehensive and coherence contents as well as having depthness in developing ideas, promotion of sense making, engagement of students, and motivation for learning (Trafton, Reys, & Wasman , 2001). Also, teachers who use more guiding questions may spend more time with students than other types of teachers, providing more opportunity for students to interact with them. Thus, students may develop their own ways of mathematical learning.

At the beginning, even though there were significant correlations between some independent variables (teachers' experience, quantity of teachers' probing and guiding questions) and dependent variable (Posttest), those relations did not remain significant in

the HLM model. This result could be explained by noting that these relationships were accounted for by other variables such as teachers' mathematics preparation and quality of probing questions.

The results of the study showed that teachers' quality of probing questions affects students' performance when teachers' mathematics preparation, textbook, and teachers' experience were controlled. The possible reason could be that teachers with higher quality probing questions provided a richer learning environment for their students by letting them not only *express their knowledge and understanding* but also *justify and interpret their understanding*. In other words, when the students had an opportunity to elaborate their thinking and understanding, they became involved with the lesson and were more likely to understand the topic being discussed. Another possible explanation for this finding could be that since the textbook and teachers' knowledge are the default components of any lesson or teaching and those two factors were also significant factors, the quality of probing questions affected students' performance when were used together with more knowledgeable teachers and higher rated textbooks. Findings of this study support the findings of Redfield and Rousseau (1981), in which they found that teachers' higher-order questions have positive effect on student achievement. In contrast to the previous research, this study considered teachers' experience, teachers' mathematics preparation, and textbooks as independent variables. Therefore, one could say that the finding of this study may be stemmed from the fact that all teachers' variables and teachers' questioning used together.

DeBoer et al., (2004) provided a model showing a linear relationship between the following four aspects: professional development, curriculum *materials*, *teacher*

*knowledge*, skills and attitude, teaching behavior, and *students' learning*. The present study supports the hypothesis of DeBoer et al., indicating that teachers' mathematics preparation and textbooks positively affected students learning. In addition, teachers who know more mathematics may be able ask more and different questions, creating a positive classroom atmosphere for learning, without fear of being exposed students' questioning. Knowing the subject matter is a crucial component in order to teach well, according to researchers such as Ball, 1991; Ma, 1999; and Mond & King, 1994. So, finding of this can be one of the good reasons to develop better teacher training programs.

The last finding of this study for the first question was that there was a significant result for the textbook. This result confirms the findings of previous research that higher related textbooks positively affected students' performance (e. g., Kulm, & Capraro, 2004; Reys, Reys, Lappan, Holliday, & Wasman, 2003; Schmidt, McKnight, & Raizen, 1997). This result occurred despite the variation of enacted curriculum delivered by the teachers. This might be so because even though some teachers don't teach from these textbooks, they use them as the main source for giving assignments and quizzes. So, students use the textbooks and benefit it.

### **The Relationship Between Teachers' Quality, Quantity, and Types of Questioning**

The findings from the second research question focused on how teachers' quality and quantity of these two types of questioning related to each other. It was found that teachers' quality of probing questions was negatively correlated with the quantity of probing questions. A possible reason for this finding can be that teachers who plan probing questions carefully don't need to ask so many of them to be effective. Another

reason could be related to do with 'wait time' (Rowe, 1974). So teachers who ask many of them don't wait for answers and thus have lower quality questions.

Teachers' quality and quantity of probing questions were positively correlated with quality and quantity of guiding questions. When teachers ask many high quality probing questions, students may need guidance and help in order to answer these open-ended questions. Also, teachers may ask higher or lower quality questions, regardless of their type. Teachers, who ask higher quality probing questions, also ask higher quality guiding questions, due to better training or planning. The last finding from this question was that there was a positive association between the quality of guiding questions and quantity of these questions. It may be that in order to ask better guiding questions, teachers need to spend more time in asking guiding questions. The implication from these findings could be that teachers need to spend more time on planning in order ask higher quality probing questions rather than asking many random probing questions. This will also provide sufficient time to ask better and longer guiding questions.

### **Teachers Ask What They Intend to Ask**

The first theme to emerge as a result of my analysis was that teachers mostly remembered what they were teaching, even though there was up to four years time lag between the actual lessons taught and the interviews. One of the two teachers who had difficulty in remembering the actual lesson has quit teaching two years before. The other teacher had changed two schools since the lesson. She had seen many different students and taught different grade levels after she changed schools.

Results from teachers' interviews showed that teachers ask what they intend to ask for both probing and guiding questions. There was a difference between teachers on



choosing indicators. For instance, one teacher chose all three indicators even though only three students out of 6 had opportunities to interact with the teacher in the video clip. Another teacher did not choose the third indicators because she said there were some students out of 20 who were only sitting and watching from crowded classroom. These differences may be due to the teachers' experience; the first teacher had taught more than ten years whereas, the other had taught less than five years. Because an experienced teacher may see if her students understood what she taught without giving chance to all whereas, a new teacher may need to make sure by asking all in order understand if they understood.

The method used for the triangulation of the data seemed helpful to increase reliability because teachers' answers to the second interview question without indicators and third interview questions with indicators were very similar. One of the important findings of this part was that one of the teachers made a distinction between *why* and *how* questions. She said that:

...A lot of times they'll tell something in my classes and I want to know how they got it. If I ask them "*why* is that?" a lot of times, kids don't know where to go. So, I usually start with *how* questions so they can explain what they did first and then I can lead them into *why* questions to make them explain little more in detail (Ms. L).

As shown in above excerpt, *why* questions require more higher-order thinking than *how* questions. Moreover, the teacher stated that it is not a good idea to start directly with *why* questions because it panics students and the students may not know how to answer. In other words, it may be a good idea to start with *how* questions and later lead

them into *why* questions if they are able to do that.

Another important finding was that another said that *articulation* is the key to learning because if students start articulating the thing they learn, they can understand what they are discussing. In other words, if a student doesn't speak out about the topic being discussed, it may mean that that student did not understand. So, one can say that being able to discuss or elaborate is a good sign of student understands of the content. Moreover, both of these were experienced teachers. They were both confident during interviews in contrast to the other two teachers. They also gave longer answers to interview questions in comparison to other two teachers. It seems clear that teachers with more years of teaching may teach more confidently with better classroom management ability than the teachers with fewer years of teaching.

For guiding questions, two teachers mentioned the use of guiding questions as re-teaching or refreshing knowledge. Also, all four teachers said that they asked guiding questions when they think either a student was stuck or did not understand the lesson. Then, it can be said that teachers use guiding questions when students need help.

### **Developing Good Questioning Skills and Habits**

How do teachers acquire their habit or skill of questionings? Several methods emerged as a result of the analysis of the interviews. Watching and observing a (good) teacher was the number one technique to learn how to ask questions. All four teachers pointed out this as a way to acquire questioning strategy. This could be the case because watching or observing teachers don't expose you any type of pressure. You are not on the spot and you only watch them how they are asking and behaving to students' responses. In this way, observers can hear questions and see good models of teaching. Later, they

can try to imitate the strategies in their own teaching. The possible disadvantage in this technique could be that watching only a few teachers may not be enough to develop a better questioning technique. The level of students and the place you will be teaching may not be the same. For instance, in small districts, it may be easier to ask any type of questions as one of the teachers said because teachers in small schools may have the advantage of knowing all their students' parents. Therefore, they can ask any types of questions confidently.

The second most used method to learn how to question was going out in the field and being in the classroom with real teachers and students:

...But when I was an undergraduate, the time in the classroom, the classroom experience, going out in the field, being in the classroom with the actual teachers and helping them out, seeing how they are doing it. You pick up things and you get exposed to different strategies in the classroom. So, I think, having the exposure in the classrooms is very beneficial because you be taught a lot with lecture at A&M or at any college but real life exposure out in the classrooms with real kids, what kind of questions kids are asking and how they are responding the questions, I think, is very helpful (Ms. L).

The advantages of being in the classroom can be that beginning teachers have an opportunity to apply what they have learned, seeing how a mentor teacher uses questions and how students react. The only disadvantage of that method could be that it is not the beginning teacher's own classroom and students. Since students know this is not their real teacher it may not be the perfect place for a student teacher to decide whether she has developed questioning skills.

The third most frequent method to develop questioning skill was workshops. However, it is not easy to find a workshop particularly focused on questioning technique. One of the teachers had more than 15 years of teaching experience and had never had a chance to participate in a workshop on questioning before her work with the MSMP project. Other three teachers did not mention workshops they benefited from in developing their questioning skills.

One of the findings of this part of the study was that questioning is not something taught in colleges. Three teachers said that there is no course or training focusing on questioning. So, during college years, teaching the research related questioning and questioning techniques could be helpful for teachers to start with. Then, during their student teaching, they could focus on several teaching methods including questioning and thus they can develop their own questioning method.

### **Implications and Suggestions for Teaching Practice**

The intention of this study was to investigate whether teachers' types, quality, and quantity of questioning affected students' achievement. In addition to that, it aimed to examine other factors such as teachers' mathematics preparation, textbook, and teachers' experience, since these factors were not considered together with questioning in most of the previous research (Carlsen, 1991). I found that teachers' quality of probing questions, teachers' mathematics preparation and quality textbook were affecting students' performance. The findings of this study on teachers' types, quality, and quantity of questioning revealed that teachers' questioning is an important factor that affects students' understanding when it is used correctly and efficiently. Therefore, the questioning skills should be considered as an important item for all teacher education

programs.

Moreover, the relationship between those two questions in terms of their quality and quantity showed that they are related with each other. The quality of probing questions tends to affect quality and quantity of guiding questions and vice versa. So, the implication of this finding could be explained that the types, quality, and quantity of questioning asked during any part of lesson may affect the flow of the rest of the lesson. Therefore, these findings can be used to organize better questioning workshops for teachers.

The qualitative part of the study accentuated the awareness of four teachers' use of questioning skill through face-to-face interviews by showing short video clips of their teachings. The analyses suggest that teachers should be equipped with better questioning skills because the teachers used in this study seemed aware of the reasons of their use of questioning. The implication is that if teachers use questioning more productively, they may get better results in their teaching and students may learn better.

For the second qualitative question, the focus was on the ways teachers acquire their questioning skills. Even though there are potential problems in drawing general conclusions and making pedagogical suggestions based on the analyses of four teachers, the suggestion is that colleges should provide better education for future teachers. First, they can improve the quality of student teaching opportunity by enriching its content. For example, student teachers can be assigned to videotape their own teaching or supervising teachers in order to examine and improve some teaching methods such as questioning. Once they focus on this, they will start developing better questioning skills. Second, they can provide more video-analysis studies for teacher candidates. Third, all four teachers

said that they did not have enough opportunity to participate in training to improve their teaching. So, another implication of this study can be that schools, districts, research agencies, and universities can organize variety of trainings including questioning to improve the quality of teaching and teachers.

### **Further Research on Teachers' Questioning**

Teachers' questioning is one of the most common teaching strategies among teachers (Cotton, 1989). The effect of questioning on student achievement has been researched for many years. In order to reveal teachers questioning skill on students understanding, one needs to control all other variables. The limitation of my study was that my sample size was not large enough to generalize. For example, it is not clear that teachers' quality of probing questions was significant because most teachers in the study had taken many math courses used highly rated textbooks. With a larger sample and random teacher data one could get better results.

One of the limitations of the qualitative part of the study was that since the MSMP only focused on teachers and did not use students' microphones, it was not always possible to hear and record students' answers to the teachers' questions. Therefore, it was not possible to validate whether the teachers asked what they intended to ask.

To what extent does student teaching affect students' questioning skill? To what extent is questioning education present in college classrooms overall? How do observing and watching good teachers change brand new teachers' questioning habit? What other questioning training methods can be effective for better questioners? These, and many others, are questions that could be investigated and whose answers could help in the

improvement of teaching and learning practices in mathematics and other subject classrooms.

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