TEACHER QUESTIONING: EFFECT ON STUDENT COMMUNICATION IN MIDDLE SCHOOL ALGEBRA MATHEMATICS CLASSROOMS

A Thesis

by

ELIZABETH APRILLA MATTHIESEN

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

MASTER OF SCIENCE

May 2006

Major Subject: Curriculum and Instruction

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Approved by:

Chair of Committee,	Robert M. Capraro
Committee Members,	Mary M. Capraro
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ABSTRACT

Teacher Questioning: Effect on Student Communication in Middle School Algebra Mathematics Classrooms. (May 2006)

Elizabeth Aprilla Matthiesen, B.S., Texas A&M University

Chair of Advisory Committee: Dr. Robert M. Capraro

This study investigates the components within teacher questioning and how they affect communication within the mathematics classroom. Components examined are the type of question, the amount of wait time allowed, the use of follow-up questions, and the instructional setting. The three types of questions analyzed in this study were high-order, low-order, and follow-up questions. High-order questions are defined as questions which promote analysis, synthesis or evaluation of information versus low-order questions which only seek procedural or knowledge of basic recall of information. The third type of question, follow-up, is the second question asked of a student when the initial question is not answered or answered incorrectly.

This study observed video of three teachers from three different adjacent school districts. Upon watching three lessons of each teacher and recording data, conclusions were made. All three teachers were found to use low-order questions at least 50% of the time during instruction. Wait time following high-order questions met the minimum three second time as suggested from previous researchers. Follow-up questions were found to occur more frequently after high-order questions, but followed similar trends as stated above related to the type of question asked. Instructional setting does differ in the

types of questions asked with a small group setting more likely to elicit high-order questions than a whole group setting. The researcher concluded that high-order questions with a minimum of three seconds wait time in a small group setting encourage communication within the mathematics classroom.

DEDICATION

To my mom,

you are the wind beneath my wings

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CHAPTER I

INTRODUCTION

Most would agree that the goal of all teachers should be the success of their students. There are many facets that contribute to a classroom where students thrive. Particularly in mathematics education, the type of instruction, the types of questions, and the amount of wait time all contribute to a classroom that fosters communication. Teachers hold the key as to how the classroom will be run. For example, the teacher can be the lecturer to a group of students, or the teacher can be a facilitator of interaction between teacher and students. Middle school teachers who create contexts for learning in which students are given opportunities to discuss their mathematical arguments and make new discoveries with their peers will lead to long-term mathematical development of their students (Lappan & Ferrini-Mundy, 1993). One of the greatest tools to guide this interaction is the posing of questions that encourage students to think on a higher level and thus respond in multiple ways. Questions can monitor comprehension, help make connections to prior learning, and stimulate cognitive growth (Vogler, 2005). Croom and Stair (2005) state that questions are best used as diagnostic tools to help indicate students' academic progress or to assess students' critical thinking. The three main types of questions to be addressed in this study are high-order, low-order, and follow-up. Black (2001) defines high-order questions as those which require students to mentally manipulate information

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The format and style of this thesis follow that of the *Journal for Research in Mathematics Education*.

they have learned and then answer with logic, reason, and evidence. Black (2001) states that low-order questions require students to recall material, either from their memory or a teacher's presentation, verbatim or in their own words. Follow-up questions are questions in which the teacher includes a previous answer given by a student into an ensuing question (Nystrand & Gamoran, 1988). Another tool for guiding communication in the classroom is the use of wait time. Wait time is the pause between the end of a teacher's question and the beginning of a student's response (Rowe, 1974). Stahl (1994) reports an average teacher pause, or wait time, to be between 0.7 and 1.4 seconds. Teachers who use a proper balance of high-order to low-order questions with a minimum of three seconds wait time will facilitate verbal communication of mathematical ideas in the classroom.

In addition, verbal expression can lead teachers to better understand a student's mastery of conceptual knowledge. Verbal expression can also benefit students' learning. Jones and Gerig (1994) state that classroom discussion "not only provides students with information needed to be academically successful, but also provides students with cognitive strategies they need to derive meaning from new information" (p.170). Jahnning (2004) conducted a study amongst middle school students with no previous algebra course experiences in solving algebra word problems, and found that students who were able to communicate their reasoning in an explicit manner were better able to make sense of the problem at hand. These possible benefits have encouraged this study which examines components of questions being posed to students and then analyzes how those types of questions compare to the amount of wait time allowed for responses. This study seeks to relate higher level questions posed by the teacher using verbal communication to positive communication by the students.

Statement of the Problem

The enactment of the No Child Left Behind legislation has caused all states to examine the quality of the assessment of their students. The Texas Education Agency (TEA) has continued to encourage higher standards for Texas students through the Texas Essential Knowledge and Skills (TEKS) curriculum. This has led to the creation of various state assessment tests, the most recent of which is called the Texas Assessment of Knowledge and Skills (TAKS). Specifically, teachers have been expected to transform their teaching to meet the higher standards of the state. One major aspect of successful teaching is the interaction between teacher and student. Teachers' choice of questions plays a major role in the type of learning that occurs within the classroom, and in turn the mastery of the concepts that are taught. Mason (2000) states, "the style and nature of questions encountered by students strongly influences the sense that they make of the subject matter" (p.97). Good questions can lead students in thinking and using communication in ways that will draw upon their prior knowledge, as well as construct new meanings to the concepts being presented (Rowman & Robles, 1998). In addition, Rogers (1972) points out that higher level questions prepare students for current and future situations in life by helping them to face problems where there are no obvious solutions. However, little has been done to make a connection between higher level questioning and student achievement on higher order mathematics problems. Are the types of questions middle grade teachers ask foundational for mathematics success?

Another component within the classroom involves the teacher's style of instruction. In their study of algebra students, Cnop and Grandsard (1998) found an increase in motivation among their students when working in small groups, as well as when they learned by communicating with other peers in the classroom. They concluded their study by stating that small groups cause students to enter into a community of mathematics where they talk about mathematics, and meanings and ideas are discussed. Whether a teacher chooses whole or small group instruction influences verbal and non-verbal communication as well as the level of questioning the teacher chooses. What are the effects of whole or small group instruction for learning? Do either of these lead to better questioning of students?

Purpose of the Study

The purpose of this study addresses two major issues. First, teacher questioning and how that questioning influences mathematical communication and learning in middle school students. Second, communication is composed of verbal and non-verbal components, so teacher behaviors and actions will also be examined for their influence on communication with middle grades students. This study specifically addresses what types of questions teachers are posing to their students, the amount of wait time they are allowing for a response, and the use of follow-up questions when students are not able to derive an answer from the initial question.

Theoretical Base of Study

This research will examine learning from the reformed-oriented mathematics view of classrooms. In this theory, learning is framed as participation in a community of practice characterized by inquiry mathematics, which is defined by students learning to speak and act mathematically by participating in mathematical discussion and the solving of new and unfamiliar problems (Goos, 2004). Likewise, students are expected to propose and defend mathematical ideas and conjectures and to respond thoughtfully to the mathematical arguments of their peers (Goos, 2004). Cobb, Boufi, McClain, and Whitenack (1997) support this notion by stating that students actively construct their mathematical understandings as they participate in classroom social processes.

Significance of Study

With the continual changes made to the state-wide TAKS test, teachers are expected to improve the quality of their instruction within the classroom. One of the pivotal changes is the quality and level of the questions being asked of Texas students. Middle school was chosen because of a steady decline in TAKS performance in grades six through eight (Texas Education Agency, 2005). This study explores the quality of teachers' questioning techniques in the classroom and how they affect student communication.

Research Questions

1. How does the number of low-order questions compare to the number of high-order questions asked by teacher in middle school algebra mathematics classrooms?
2. Is there a relationship between the type of questions asked and the amount of wait time allowed to answer in middle school algebra mathematics classrooms?

3. How often were follow-up questions asked after low-order questions as compared to high-order questions in middle school mathematics classrooms?
4. What influence does a group setting have on the use of high-order or low-order questions in middle school mathematics classrooms?

Definition of Terms

High-order Questions: questions that encourage students to analyze, synthesize, or evaluate information presented in order to provide a solution (Wimer, Ridenour, Thomas, & Place, 2001).

Low-order Questions: questions that are procedural or knowledge-based, which ask students to recall an answer straight from memory (Wimer et al., 2001).

Follow-up Question: a second question posed to an individual student when the initial question is not answered or is answered incorrectly.

Wait Time: the interval between the end of a teacher question and the start of a student response (Rowe, 1986).

Rephrase Technique: restating a question to clarify what is being asked.

Reteach Technique: a question that redirects the student to previous learning.

Limitations

This study is limited to three teachers who volunteered to be observed. The teachers were part of a bigger program whose purpose was to observe curriculum that was being implemented; they were not aware that the components within their questioning were being observed. Due to the volunteering of teachers, some of the results of this study may not be to generalize all of the results found. It is also important to note that this study is an exploratory study that intends to provide a basis for further study.

CHAPTER II

REVIEW OF LITERATURE

This chapter presents an overview of various components related to teachers' questions. First, background information regarding recent expectations in mathematics education is presented, followed by research discussing the need for good questioning in the classroom. Next, an overview of related theoretical and practical research on the components of teacher questioning is offered. Finally, a summary and significance of research to mathematics education section is presented.

The purpose of this research was to study teachers, their questioning techniques, and how they influence students' communication in the classroom. This research focuses on various components related to teachers' questions. These components include the types of questions posed, the amount of wait time given to respond, and follow-up questions asked in order to elicit more communication. This research sought to show that a teacher's effective use of all these aspects within questioning would lead students into good mathematical communication within any given classroom.

The National Council of Teachers of Mathematics (NCTM) defines one of the pivotal areas in mathematics instruction to be communication (p.61). More specifically, instruction should enable students to organize and consolidate their thinking through communication, communicate their mathematical thinking clearly to peers, teachers, and others, and use the language of mathematics to express mathematical ideas clearly (NCTM, 2000). There are many different instructional approaches used to facilitate communication in the classroom. Instructional approaches include verbal communication through discourse or written communication through the use of pictures, numbers, or words. Specifically, verbal communication can be found in instruction that asks high-order and follow-up questions and allows students appropriate wait time to respond. Therefore, verbal communication is being used as the focus of this research. Questioning is one approach commonly associated with students' verbal communication. It has been stated that teachers spend thirty-five to fifty percent of their instructional time asking students questions (Black, 2001). Moyer and Milewicz (2002) define questioning as the most frequently used instructional tool.

Components for Facilitating Communication

The Teacher's Role

What impact do teachers have in the asking and responding of questions? The teacher's role in helping students develop deep mathematical understanding is multifaceted. A good facilitator of communication is one who is able to get students to explain things so well that they can be easily understood (Reinhart, 2000). Students learn to think mathematically by being in the presence of a relative expert who makes their thinking processes explicit by encouraging mathematical communication (Vygotsky, 1978). Teacher-student interaction is claimed to be one of the most important factors contributing to the development of communicative competence (Golkar, 2003). It is this focus on the teacher that drives the research of this study. The three components for facilitating communication are asking, listening, and responding. Some might argue that listening is more important than asking, or that responding is more important than listening, but one component without the others does not work in the process of facilitating communication. The teacher is responsible for initiating discussion through the choosing of appropriate questions, listening to student responses to gage the need for possible further discussion, responding to student responses and choosing the style of instruction within the classroom.

The first factor of teacher-facilitated communication is asking questions that lead to discussion and communication of mathematical ideas. In order to ask appropriate questions, teachers need to be knowledgeable about the content domain. These questions should provide opportunities for students to reinvent mathematical ideas through both exploration and refining of previous ideas (Martino & Maher, 1999). Likewise, tasks should make it necessary for students to analyze other tasks, find distinguishing features between tasks, and verbalize generalizations about tasks (Wolfram, 1997). Along with the creation of questions comes the creation of productive discussion. Teachers must find a balance between focusing on the processes of discussion and focusing on its content. The engagement in the process of discussion includes how the teacher and student interact during discussion: who talks to whom, when, and in what ways. The content of discussion refers to the substance of ideas raised and the depth and complexity of these ideas in terms of the mathematical concepts in the context of the discussion (Sherin, 2002). Teachers must understand that questioning is a skill, and like all other skills it must be practiced before it can be mastered to its best potential (Vogler, 2005). Effective communication requires teachers to ask good prepared questions, but also requires good listening to student responses.

The second factor of teacher-facilitated communication is listening to student's responses in order to determine the need for further discussion. As a listener, teachers must learn to focus on the student's response so they can gage where to go next in the discussion. Wasserman (1994) states that the act of listening requires a full and conscious effort to tune into the 'how and what' of the student's ideas. Too often teachers listen for what they want or what they expect the students to say rather than listening for the student's thinking and reasoning. Upon listening to student's responses, teachers must then decide how they will respond to the student's comments.

The next factor involves the teacher's response to student's responses. As a responder, teachers must listen and comprehend a student's ideas or comments and weigh the various options so an appropriate response is given (Nicol, 1999). Responding goes hand in hand with listening. It is much easier to respond if one listens to the student's thinking. Tobin (1986) gives several alternatives that teachers face when deciding how to respond to a student. Those alternatives include whether to paraphrase the student's answer, provide an explanation, ask another question, move on to a new topic, allow the student to continue to speak, or to call on another student to respond (Tobin, 1986). One way a teacher can respond to a student's thinking is by using follow-up questions. Using follow-up questions within a given task demonstrates the teacher's attention towards the child's thinking. Teachers often use these questions to gain further insight to or clarification of ideas communicated by their students. This strategy communicates to the child that the answer is still open for discussion (Moyer & Milewicz, 2002).

Style of Instruction. The final factor is the teacher's style of instruction within the classroom. There are two main styles of instruction within the classroom: small group or student-centered instruction, and whole-group or teacher-centered instruction. Cnop and Grandsard (1998) define the small group instruction as a method where students work cooperatively in groups to work out the details of a given problem, construct new examples of the problem, and formulate hypotheses about the problem so as to find a solution. The teacher becomes the facilitator among the different groups and offers suggestions, gives encouragement, and corrects misunderstandings. In their study of algebra students, Cnop and Grandsard (1998) found an increase in motivation among their students when they worked in small groups or learned by communicating with other peers in the classroom. They concluded their study by stating that small groups cause students to enter into a community of mathematics where students talk about mathematics, and meanings and ideas are discussed. DePree (1998) also conducted a study of algebra students who worked collaboratively; they found that confidence increased and students stated that learning in groups was easier because other students within the group helped them to understand the problem at hand. Nystrand and Gamoran (1990) have found this type of instruction beneficial to communication within the classroom because students have some input into and control over the communication.

The second style of instruction is whole group or teacher-centered instruction. Evans (2000) defines this type of instruction as one where the teacher takes on the role of being the sole provider of information through lectures, leaving students to take notes. The amount of teacher-student discussion is limited, thus causing the student to take a passive role in the learning. Nystrand and Gamoran (1990) define this type of instruction as recitation, or the process by which the teacher initiates and dominates communication and students are passive and expected to recall what they have learned or report other people's thinking. Whole class settings have also been found to provide limited opportunities for talk that would allow students to evaluate their own thoughts and learning experiences (Myhill, 2006).

Question Typology

The second component is the types of questions that teachers pose to their students. Nicol (1999) explained that teachers posing certain types of questions do not lead to positive mathematical learning outcomes. The tension was related to posing questions that examined what students were thinking versus posing questions to get students to provide factual information or questions to assess students' knowledge. In order to know when to pose different types of questions, one must know how a certain type of question is defined so it can be effectively used in instruction. Likewise, one must also know the type of response different types of questions will elicit so that instruction will be successful for students' understanding of concepts. The three major hierarchical question types teachers can pose to be discussed are high-order, low-order, and follow-up.

Other researchers refer to high-order and low-order questions by other names. For example, high-order questions have been called open-ended, interpretive, evaluative, inquiry, inferential, or synthesis questions. Low-order questions have been known as closed, direct, recall and knowledge questions (Black, 2001).

High-Order Questions. One of the types of questions that is interesting is commonly referred to as high-order. High-order questions are defined as those questions that the teacher is not predisposed to expect a specific answer (Golkar, 2003). High-order questions are those that promote analysis, synthesis, and evaluation of information (Wimer et al., 2001). One of the most notable researchers to explore various levels of student cognitive learning is Benjamin Bloom. Bloom created a six-level taxonomy for intellectual behavior. Bloom, Englaehart, Furst, Hill, and Krathwohl (1956) identified four levels in their taxonomy: application, analysis, synthesis, and evaluation. These four levels use high-order questions to engage the students in communication. At the application level, students are asked to apply facts, principles or generalizations that are known to solve a problem. Croom and Stair (2005) identified apply, choose, demonstrate, or illustrate as possible verbs found in the questions asked at the application level. The analysis level asks students to identify and comprehend elements within a process, communication, or series of events. Possible verbs found in analysis questions include analyze, appraise, calculate, or compare (p. 14). Synthesis questions will ask students to engage in creative thinking. When a teacher asks a synthesis question, he/she might be found using the verbs arrange, compose, create, or design (p.14). Evaluation, or the highest questioning level, asks students to determine how a concept or idea is consistent with standards or values. This level of question might include verbs such as appraise, assess, choose, or argue (p.14). Only about twenty percent of teachers questions are usually high-order (Black, 2001).

Several studies have been done in relation to high-order questions. Rickards (1974) found that the use of high-order questions stimulate cognitive processing behaviors, which influence the recall of both relevant and incidental material. Nystrand and Gamoran (1990) state that these types of questions signal to students the teacher's interest in what they think, not just what they know and can report about what others have said. Ostergard (1997) concluded that teachers who were able to use high-order questions learned how to promote significant student communication in the classroom. Hamm and Perry (2002) state that high-order questions communicate the view that mathematics is a discipline in which there are multiple pathways to understanding, and these pathways can be evaluated individually for their own merit by the community. In her study, Golkar (2003) found that high-order questions lead to more elaborate and extended forms of conversation, as well as engage students in meaningful interaction. Croom and Stair (2005) concluded that high-order questions allow teachers to encourage their students to be more creative and analytical in their thinking.

Moyer and Milewicz (2002) list different categories of high-order questions that all lead to different aspects of mathematical learning. First, a question that helps a student make sense of mathematics could be "can you explain to me why that makes sense?" Second, a question that helps students rely more on themselves to determine if something is correct could be "how did you reach that conclusion?" Third, a question which helps students learn to reason mathematically could be "how could you prove that to me?" Fourth, a question which helps students conjecture, invent, and solve problems could be "what would happen if?" Finally, a question that helps students connect mathematics, its ideas and applications could be “have we solved any problems like this before?”

Low-Order Questions. Another question type of interest is commonly referred to as the low-order question. Low-order questions are defined as those questions where the teacher attempts to predict the students answers before asking the question (Golkar, 2003). Myhill and Dunkin (2002) define low-order questions as those that have a pre-determined answer. Low-order questions are also defined as procedural or knowledge-based questions that address information. Two levels of Bloom’s taxonomy are knowledge and comprehension (Bloom et al., 1956); these two levels ask students low-order type of questions. The knowledge, or lowest, level asks a student to recall information. Croom and Stair (2005) note possible verbs in knowledge level questions as arrange, define, label or list. When students are asked to put information in another form, then they are at the comprehension level of Bloom’s taxonomy. At this level, teacher questions might include the verbs describe, discuss, explain or identify (Croom & Stair, 2005). A typical student response to a low-order question generally requires a straight answer from memory rather than a more complex answer (Wimer et al., 2001; Gall, 1984). In a study among mathematics classrooms in Germany, Japan, and the United States, Kawanka and Stigler (1999) found that the emphasis in U.S. classrooms is still asking students to communicate already known procedures and principles rather than individual ideas and thinking processes. Yip (2004) reiterates the notions regarding low-order questions by stating that low-order questions are used primarily in science classrooms to assess the knowledge level of students. Hamm and Perry (2002) state that low-order questions send the implicit message that mathematics is a discipline in which the teacher always knows the answers and creative solutions are not valued. In general, most classroom discussions involve more than fifty percent of low-order questions (Black, 2001). This notion is supported by Myhill and Dunkin's (2002) study, which found that teachers ask low-order questions sixty-four percent of the time during instruction.

There are several common forms or types of low-order questions; one is a method known as "checklisting." "Checklisting" is simply reading through a list of questions, obtaining an answer from the student, and moving on to the next question without any probing into the student's thinking (Moyer & Milewicz, 2002). A second form of a low-order question is one that seeks an answer based on basic knowledge recall. For example, a teacher might ask, "What is the answer to a multiplication problem called?" A third form of a low-order question is one that looks for an answer based on a mathematical procedure. For example, "When adding two numbers together, at which place do I begin?"

Follow-Up Questions. The final area of study regarding types of questions is that of follow-up questions. Follow-up questions are defined as questions in which a teacher incorporates a previous student answer into a subsequent question (Nystrand & Gamoran, 1988). These questions are often found to use pronouns because the pronoun refers back to the previous answer given by the student (Nystrand & Gamoran, 1988). Kawanaka and Stigler (1999) referred to follow-up questions as guiding questions. These questions guide students to discuss problems and derive mathematical concepts and procedures, or they guide students to use certain mathematical concepts and procedures to solve problems (Kawanaka & Stigler, 1999). Follow-up questions can go both ways: students can inquire about the teacher's remarks or the teachers can inquire about the students remarks' (Nystrand & Gamoran, 1990). For the purpose of this study, only follow-up questions were examined from the teacher's perspective.

Very few studies have focused on follow-up questions. Of the studies done, there have been mixed findings. Sahin and Kulm (2006) have found follow-up questions to provide students with a hint or suggestion about the next step towards the solution, as well as a sequence of ideas to lead students toward independent thinking. Wright and Nuthall (1970) found a positive correlation between student gains in learning and follow-up questions. However, later researchers found no effect between follow-up questions and student gains (Gall et al., 1978; Hughes, 1971). In Kawanaka and Stigler's study (1999), follow-up questions in U.S. classrooms were more often found to guide students to use certain mathematical concepts and procedures rather than guiding them to discuss the problems and comprehend mathematical concepts. One explanation for the differences in findings could be the context in which follow-up questions were conducted within each study.

Follow-up questions can be very beneficial to communication within the classroom. First, when teachers are exercising the use of follow-up questions during instruction, they must pick up on what students have said and then weigh the possibilities for discussion so that it can be weaved into the exchange of communication within the classroom (Nystrand & Gamoran, 1990). Second, these questions function to chain together teacher questions and student responses, making the communication within the classroom much more coherent (Nystrand & Gamoran, 1990).

Wait Time

The third and final component considered is the teacher's use of wait time when asking questions. Rowe (1974) defines wait time to be the time between when the teacher stops speaking and the student responds or the teacher speaks again. On average, students are only allowed one second of wait time to start an answer (Rowe, 1974). In her study, Rowe (1974) noted differences in interaction between the teacher and students when wait time increased to three seconds or more. Several benefits for both the student and teacher were found when a minimum of three seconds of wait time was allowed. Benefits for the student included longer and more correct responses, fewer "I don't know" responses, more volunteers, appropriate responses by larger numbers of students, and scores on achievement tests tended to increase (Rowe, 1974; Stahl, 1994). Teacher benefits found were more flexibility and variety in their questioning strategies, and the quantity of questions was replaced with higher quality of questions (Rowe, 1974; Stahl, 1994). In addition, Rowe (1986) also found more coherence in discussion between students and students and teacher, as well as improved motivation, which led to improved discipline in the classroom. Rowe (1978) added to previous research by stating that a minimum of three seconds wait time restructured the learning by shifting students to an evaluation of their thoughts and the thoughts of others in the classroom.

Another aspect that affects wait time is the rate at which a teacher presents information, as it should match the cognitive processing abilities of the students (Tobin, 1986, 1987). Thus, teachers should supply sufficient time for students to think about the question and engage in communication. In mathematics classrooms, Tobin (1986) found that when extended wait time were given, there was an increase in application questions and a decrease of questions seeking basic comprehension. Likewise, students were given more opportunities to apply the instructional objectives and verbally participate in communication (Tobin, 1986). In a later study, Tobin (1987) noted the silence during the wait time gave teachers time to think and develop higher quality communication that influenced the thinking and responding of the students.

Creating a learning environment in which all students are given opportunities to participate in ways that not only enhance their learning but also the learning of others in the classroom can be related to the wait time allowed by the teacher. In Henningsen and Stein's (1997) study of how classroom-based factors shape students' engagement in mathematical tasks to encourage high-level mathematical reasoning, they found the amount of wait time to be a very important factor. When an appropriate amount of time was given for discussion of the problems, the students were given opportunities to consider and discuss multiple solution strategies for the problem given (Henningsen & Stein, 1997). Wilen (2001) notes that students from all levels become frustrated when teachers do not give them sufficient time to think. Allowing a few seconds of wait time can also increase the probability of a more thoughtful and supported response. Wilen (2004) notes wait times of three to five seconds can increase the quantity and quality of student responses. Students must be given time to understand the question, connect the content to past knowledge and experiences, formulate a response, and express their response (Wilen, 2004).

Summary

Communication in the classroom involves the interaction between teacher and student. This study has focused on verbal communication through the tool of questioning, and good questioning could start with the student or the teacher. While there is much to be discussed regarding student-initiated questions, this research has focused on the teacher's initiation of questions. The teacher plays multiple roles as a facilitator of communication, which includes asker, listener, and responder. In addition, the teacher must focus on the actual types of questions asked and the amount of wait time given for students to respond.

Teachers must provide an instructional environment for learning, and they must decide which types of questions to ask so that good communication of mathematical ideas will occur. They follow the asking of different questions with listening to student's responses. Teachers must listen to each student's response in order to determine if further explanation is needed from the student. Upon listening to students' ideas, the teacher then must respond to each student's ideas in a manner that further encourages communication of their thoughts or edifies the communication of thoughts already given. Students must feel that the classroom is a safe place where all responses are valued, whether it is in a whole group setting or small group setting.

Students can be asked high-order or low-order questions, but research indicates that high-order questions are better for communication in the classroom. High-order questions cause students to analyze, synthesize or evaluate the material presented, thus creating better communication of mathematical ideas. Sometimes the initial question does not provide enough information for the teacher to determine conceptual understanding on the part of the student. Thus, a follow-up question is needed to elicit further explanation and communication of ideas from the student. A balance between high-order and low-order questions with the possibility of follow-up questions along the way will create a positive environment for the communication of mathematical ideas in the classroom.

After a question is posed to students, an allowance of significant wait time is necessary to provide beneficial results of communication within the classroom. Teachers must give their students a minimum of three seconds wait time to think about the question being asked so they can formulate a thorough response. When three seconds of wait time are allowed students will be best able to communicate in a manner which allows for well thought out responses.

This study hopes to provide teachers with a method to extract communication of mathematical conceptual understanding from their students. Through the use of proper questions and significant wait time the researcher expects this outcome to occur. The following chapter will discuss the collection of data related to the types of questions asked and the amount of wait time allowed, to the second. Chapter III will also discuss how the data will be analyzed so that relationships can be made between types of questions, wait time, and the instructional setting. The specificity of this research in analyzing teacher questioning techniques as they are related to student success in communication of higher level mathematical cognitive tasks will help teachers better understand the necessity to use higher level questioning strategies in their classrooms.

CHAPTER III

METHODOLOGY

In this chapter, the procedures and research design used in attaining the aims of the study are presented and discussed. The purpose of this study was to investigate teacher questioning and how that questioning influences mathematical communication and learning in middle school students. This chapter begins with a description of the sample used in the study. Second, the instrument used to collect data is described. Third, reliability assurance procedures are given. Finally, the chapter concludes with an explanation of the analysis procedure conducted in the study.

This study utilized a within-stage mixed-model design (cf. Johnson & Onwuegbuzie, 2004), where initially the data were analyzed quantitatively to investigate the overall implications, and this was followed by a qualitative analysis. Several components of teacher questioning were chosen to analyze quantitatively. For example, the type of question asked, the amount of wait time allowed for students to respond, and the frequency of a follow-up question to the original question.

In order to understand the nature and structure of the participants' questioning, the quantitative results were used to inform the selection of a purposeful sample for qualitative analysis. The sample chosen for qualitative analysis were the teacher's structure of instruction and behaviors when asking questions of students. Through constant comparison, similarities in techniques were identified and unifying commonalities were used as meta-categories (Denzin & Lincoln, 2000).

The major research questions framing this study were:

1. How does the number of low-order questions compare to the number of high-order questions asked by teacher in middle school algebra mathematics classrooms?
2. Is there a relationship between the type of questions asked and the amount of wait time allowed to answer in middle school algebra mathematics classrooms?
3. How often were follow-up questions asked after low-order questions as compared to high-order questions in middle school mathematics classrooms?
4. What influence does a group setting have on the use of high-order or low-order questions in middle school mathematics classrooms?

The Research Sample

The sample for this study was three middle school mathematics teachers. All three teachers taught at different schools in adjacent school districts. Teacher 1 taught in a school district with approximately 10% "low SES" and minority students versus teachers 2 and 3 who taught in districts with 60% "low SES" and minority students (Kulm & Capraro, 2004). All three schools were small (n < 375) and located in rural areas.

Teachers 1 and 3 both worked in schools with at least a 68% white population. Hispanic and African American populations were between 11% and 18%. Teacher 2 taught in a more diverse school where the population was 46% Hispanic, 37% white, and 16% African American.

All participants gave permission to be videotaped and also permission for those tapes to be used for research purposes as part of the larger *Middle School Mathematics*

Project (MSMP). Three videotaped lessons occurring within the 2003-2004 school year were used for each teacher. The lessons ranged from twenty-three to forty-one minutes. Each class consisted of about twenty-five students.

Instrumentation

An instrument called the "Teacher Questioning Components Instrument" (see Appendix A) was designed by the researcher to record the frequencies of each component of teacher questioning for use in this study. The instrument was designed so that as a teacher asks a question each of the remaining components could be studied. The instrument has four major components. Those components include: (1) the type of question, (2) wait time, (3) follow-up question, and (4) comments. In the following sections, the components of the instrument will be described.

Types of Questions

The first component within the instrument was the type of question asked by the teacher. The two types of questions to be coded in this section of the table are high-order and low-order questions. High-order questions were those considered to require analysis, application or explanation of the idea in question. Therefore, when the teacher asked a question that required the student to give more than a one or two word answer, it was coded as high-order. For example, teachers observed asked questions such as "How did you know that?, Why do you think?, and What is happening here?" High-order questions also require the student to explain their thinking or a process used to answer the question. These questions involved an answer that the teacher was not predisposed to expect ahead of time. High-order questions were coded with an "H" in the type of question column of the table. Low-order questions were defined as those requiring a yes/no answer, any type of procedural question, or those questions that came about by teacher guidance and resulted in a one-word answer. Low-order questions were those that the teacher knew the answer to before they were asked, were more direct, and required a specific one or two word answer. Examples of low-order questions that were asked were “How many seconds are there in two minutes?, What’s the pattern?, or How many weeks did they tell us?” Low-order questions were coded with an “L” in the type of question column of the table.

Another factor when determining the type of question were the verbs used in the question. As mentioned in Chapter II, Croom and Stair (2005) listed some of the verbs in high-order questions as demonstrate, compare, or create, and some of the verbs in low-order questions to be list, define, or identify. It is important to note that reliance on looking at just the verbs within the question would not be enough for determining the type of question. Although the verbs mentioned have been attributed to certain types of questions, the entire content of the question must be taken into account when determining its type.

Wait Time

The second component the instrument recorded was wait time, which was coded to the nearest second per question. Wait time began when the teacher stopped talking at the end of the question and ended when either the teacher began talking again or the student responded. A timer on the computer was used in counting the seconds of wait time allowed by the teacher. For example, if a teacher waited four seconds between the end of the question and the next response, then a “4” was put into the wait time column for that question. Wait time can be very difficult to record because of different interpretations of when the actual pause begins and ends. Wait time can also be very brief within a given context. In order to ensure accuracy of the wait time, the video was rewound as many times as necessary any time a question’s wait time was not clear.

Follow-up Questions

The third component of the instrument was follow-up questions. Follow-up questions were defined as a subsequent question asked to the same student after the initial question either produced no response or an incorrect response. If the teacher asked a question related to the original question to a different student, then it was coded as a new question. It is important to note here that follow-up questions can be interpreted in many ways. For example, a follow-up question can be any question a teacher asks to follow-up a previous question, or it can be a question that is student-initiated. For the purpose of this research, only a second question redirected to the same student as the original question was considered a follow-up question. Follow-up questions were coded a “Y” if the teacher provided a follow-up question to the student and a “N” if the teacher did not provide any follow-up question. In addition to recording a “Y” when a follow-up question was asked, the researcher also recorded the type of question the follow-up question was. This was noted in parenthesis as an “H” for high-order and an “L” for low-order. The researcher used the same factors as stated earlier for determining a high-order or low-order question.

Comments

The final component of the instrument was called comments. This section of the instrument was used in recording the questions asked by the teacher. While observing the types of questions being asked, other things began to appear within the instruction. The researcher used this section of the instrument to also record a comparison of the teacher's instructional setting, as well as techniques when waiting for students to respond to the follow-up question. Instructional settings included whole group lessons, small group lessons, or a mixture of both. Examples of techniques included body language, eye contact, head nodding, pointing to items, rephrasing, and reteaching.

Estimating Reliability

In order to ensure the reliability of the data from the Teacher Questioning Components Instrument and adequately evaluate it, a second researcher was trained to identify high-order and low-order questions based on Moyer and Milewicz and (2002) and Bloom et al. (1956) definitions and the question enactments in the mathematics content related videos as well as the wait time and follow-up questions. The primary researcher composed a list of thirty-one actual questions used by the three teachers observed. The thirty-one questions chosen were not among the questions the second researcher was asked to code from the video segments. The primary researcher only used the first sixteen questions in the first round of training, and the remaining questions were omitted in case retraining was needed. The second researcher was asked to code each question as high or low-order. Upon completion of this coding a score was obtained by dividing the number correct by sixteen. The inter-rater reliability score was .94 after training. This surpassed the .80 minimum, thus no retraining was necessary. The second researcher was then asked to observe approximately 20 questions during specific segments of each teacher's video, approximately in the middle of each teacher's instruction (see Appendix B). The segments used came from teacher 1's lesson one, teacher 2's lesson two, and teacher 3's lesson three. While watching these segments of video, the second researcher coded using the Teacher Questioning Components instrument (see Appendix A). Each segment coded required sixty pieces of data on the instrument (twenty type of questions, wait time, and follow-up questions) yielding a total of 180 total pieces of data at the end of the video segment coding. The final inter-rater reliability was computed at the completion of the second rater's video segments. A minimum agreement of .80 was required. The second inter-rater reliability was scored as .88, thus achieving the goal of more than .80, and no further training was needed.

Intra-rater reliability was computed by recoding the primary researchers initial coding of video segments from the beginning, middle, and end of the initial coding process. Intra-rater reliability was attained at a level of .97. This level surpassed the .90 minimum and no recoding was necessary.

Data Analysis

To answer research question one, data were analyzed by the quantity of each type of question. High-order and low-order questions were compiled and totaled per teacher. This compilation was put into a spreadsheet with two columns labeled teacher and question type. The teacher column was recorded as a "1" for teacher 1, a "2" for teacher 2, and a "3" for teacher 3. Question type was coded a "0" for low-order questions and a

"1" for high-order questions. A chi square test was run to compare the observed and expected frequencies of high-order and low-order questions per teacher observed. Significance was determined from this data.

To answer research question two, data were analyzed by the amount of wait time allowed after each question was asked. Wait time was also compiled and totaled per teacher. This compilation was put into the same spreadsheet containing the teacher and question type. A third column was created and labeled as wait time. Wait time was recorded as the number of seconds allowed per question. An independent t-test was run to compare the amount of wait time to the type of question asked.

To answer research question three, data were analyzed by totaling the number of follow-up questions asked after high-order and low-order questions. These totals were divided by the overall total of high and low-order questions to find a percentage. These percentages of follow-up questions to high and low-order questions were recorded in a table to compare the three teachers observed. Second, the type of question recorded in parentheses for each follow-up question were totaled and divided by the overall total of follow-up questions per teacher, and a percentage was found. These percentages were graphed to show the differences between the three teachers.

Finally, to answer research question four, the researcher used data related to the type of instruction from the comments section and conducted a chi square test to analyze the frequency of high versus low-order question by the type of instructional setting for these questions. In order to run the chi square test, a third column labeled instruction type was added next to the question type and amount of wait time. A "0" was recorded as a small group instructional setting and a “1” was coded as a whole group instructional setting.

CHAPTER IV

RESULTS

This chapter presents a discussion of the analysis found for the variables of types of questions asked, the wait time allowed, and the follow-up questions asked. In addition, the type of instructional setting, including teacher behaviors while waiting for students to respond, is compared to the analysis of the three variables within teacher questioning. The chapter concludes with a summary of the results found in this research.

Analysis of Variables within Teacher Questioning

Types of Questions

The first variable analyzed was the types of questions asked by the teachers. All three teachers had a higher occurrence of low-order questions compared to high-order questions. Table 1 presents the percentage of high-order questions compared to low-order questions used in the observed lessons. As a whole, all three teachers combined resulted in a 78% to 22% ratio of low-order to high-order questions. Teacher 1 had approximately a 70% to 30% ratio of low- to high-order questions, teacher 2 had a 76% to 24% ratio of low-to high-order questions, and teacher 3 had a 95% to 5% ratio of low- to high-order questions. Interestingly, in previous research done by Black (2001), found teachers ask high-order questions 20% of the time during instruction. The confidence interval was created around Black's computation of 20% to see if any of the teachers observed in this study follow that research. The lower limit was found to be 16% and the upper limit was found to be 24%. When you combine the teachers' results the data does fall within this confidence interval. However, when looking at each individual teacher, only teacher 2 falls within this interval. Myhill and Dunkin (2002) also found that on average low-order questions were asked 64% of the time. Once again, a confidence interval was computed and found a lower limit of 61% and an upper limit of 68%. All three teachers observed did not fall within this confidence interval.

Table 1

Comparison of Teachers to Type of Questions Asked

			Teacher			
			1	2	3	Total
Type of Question	0	Count	134	216	112	462
		Expected Count	146.7	223.2	92.1	462.0
		% within Questiontype	29.0%	46.8%	24.2%	100.0%
		% within Teacher	71.3%	75.5%	94.9%	78.0%
	1	Count	54	70	6	130
		Expected Count	41.3	62.8	25.9	130.0
		% within Questiontype	41.5%	53.8%	4.6%	100.0%
		% within Teacher	28.7%	24.5%	5.1%	22.0%
Total		Count	188	286	118	592
		Expected Count	188.0	286.0	118.0	592.0
		% within Questiontype	31.8%	48.3%	19.9%	100.0%
		% within Teacher	100.0%	100.0%	100.0%	100.0%

To determine significance, a chi-square test was run to compare each teacher to the types of questions asked. The chi-square test was used to test the null hypothesis that the teachers do not differ. This test is more effective when data are not normally distributed but just as effective in the case the data are univariate normal. The chi-square test revealed that the types of questions asked differed by teacher, χ^2 (1, N = 592) =25.683, p <.001 (see Table 2). Teacher 2 had the highest total of questions at 286, with

216 being of low-order type and 70 being high-order; teacher 1 asked the second highest number of questions at 188, with 134 being high-order and 54 being low-order; and teacher 3 asked the least number of questions at 118, with 112 being low-order and 6 being high-order. Thus, the results are significant. The researcher concludes that the teachers do in fact differ with regards to the types of questions they asked of their students.

Table 2

Chi-Square Test Comparing Type of Questions Asked by Each Teacher

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	25.683	2	<.001
Likelihood Ratio	32.026	2	<.001
Linear-by-Linear Association	20.831	1	<.001
N of Valid Cases	592		

Wait Time

The second variable analyzed was wait time. The researcher began to run the statistical tests on the variable wait time and found that an outlier was present in the data. The outlier was a wait time of 40 seconds. In order to provide a more accurate analysis and prevent any data from being skewed, this particular case of the data was removed.

A mean score was calculated for wait time occurring after high-order and low-order questions. The mean score for wait time after a high-order question was found to be 4.54 seconds (see Table 3). The mean score for wait time after a low-order question was 2.56 seconds (see Table 3). In addition, a minimum and maximum score was found for wait time to two standard errors. The minimum and maximum for low-order questions was 1.801 and 2.698 seconds, respectively (see Table 3). These calculations show that low-order questions still did not fall within the three second minimum as stated in previous research (Rowe, 1974; Stahl, 1994). The minimum and maximum for high-order questions was 3.996 and 5.084, respectively (see Table 3). The researcher also decided to construct the confidence interval around the mean of three seconds, as given in previous studies (Rowe, 1974; Stahl, 1994). For low-order questions, the confidence interval was found to be a range of 2.86 to 3.14 seconds; and high-order questions were found within a range of 2.47 to 3.53 seconds. In both types of questions, the data fall outside the confidence interval. The data show that low-order questions fall very close to the previous research, which states that a minimum of three seconds is needed for students to respond. However, the findings for high-order questions do not seem to follow this rule, but rather require more than the three second minimum.

Table 3

Descriptive Statistics for Wait Time Related to High and Low-order Questions

Type of Question	N		Std. Deviation	Std. Error Mean	Min (2 standard errors)	Max (2 standard errors)
0	462	2.56	1.474	.069	1.801	2.698
1	129	4.54	3.090	.272	3.996	5.084

A Levene's test was run to determine equal variances among the variable wait time. The researcher assumed an F test to be significant at the .05 or less level. When looking at the data, wait time was found to have an F test significant. The variances were assumed to be unequal in the variable wait time (see Table 4). Therefore, the lower line of Table 4 was used.

Next, a *t* test was chosen to compare two independent groups. The two groups were mean wait time after low-order questions and mean wait time after high-order questions. The researcher sought to find out if there was a significant difference between the two independent groups. In order to determine this significance, a *t* test statistic was run to test for equality of means between the two types of questions. A prior alpha level was set to .05 as the upper limit of significance. The total number of high-order questions asked by all teachers (M = 4.54, SD = 3.09) found a longer amount of wait time as compared to the total number of low-order questions asked by all teachers (M = 2.56, SD = 1.474), $t(591) = -7.065$, $p < .001$ (two-tailed), d = .155 (see Table 4). Thus, the mean wait time for high and low-order questions differed significantly.

Table 4

Independent Sample T-Test on Wait Time Variable

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
	67.228	.001					.		
Equal variances not assumed			-7.065	144.625	<.001	-1.982	.281	-2.537	-1.428

Follow-up Questions

The third variable analyzed was the follow-up questions teachers asked after the original question. Table 5 presents the percentage per teacher of follow-up questions that were asked after high-order and low-order questions. There were a total of 53 follow-up questions asked after a total of 130 high-order questions and 138 follow-up questions asked after a total of 462 low-order questions. This computes to 41% of high-order questions containing a follow-up question and 30% of low-order questions containing a follow-up question. Therefore, follow-up questions were more prevalent after high-order questions. A further breakdown by teacher is given below.

Table 5

Percentage of Follow-up Questions Following High-order and Low-order Questions

Type of Question	Teacher		
	1	2	3
High-Order	54	70	6
Follow-up questions after high-order questions	16	35	2
Number of high-order follow-up questions after original high-order question	6	9	2
Number of low-order follow-up questions after original high-order question	10	26	0
Percentage of follow-up questions to total high-order questions	30%	50%	33%
Low-Order	134	216	112
Follow-up questions after low-order questions	30	81	27
Percentage of follow-up questions to total low-order questions	22%	38%	24%

Table 5 indicates teacher 1 asked follow-up questions 30% of the time after a high-order question and 22% of the time after a low-order question. In addition, Table 5 reveals that teacher 2 asked follow-up questions 50% of the time after high-order questions and 38% of the time after low-order questions. Finally, Table 5 presents teacher 3 with follow-up questions 33% of the time after high-order questions and 24% of the time after low-order questions.

Each follow-up question was classified as either high-order or low-order. The percentage for each type of classification is shown in Figure 1. Of the forty-six follow-up questions asked by teacher 1, 70% were low-order and 30% were high-order. Teacher 2 asked a total of one hundred sixteen questions 73% low-order and 27% low-order. Teacher 3 had 90% low-order and 10% high-order of the twenty-nine follow-up questions asked. These percentages closely match earlier findings of high-order and low-order questions related to the original question asked. Teacher 1 had exactly the same percent of high-to low-order questions originally as during follow-up questions; teacher 2 had only a 3% difference with the original questions yielding a 76% to 24% low-to high-order; teacher 3 was found to have only a 5% difference with the original questions producing a 95% to 5% of low-to high-order.

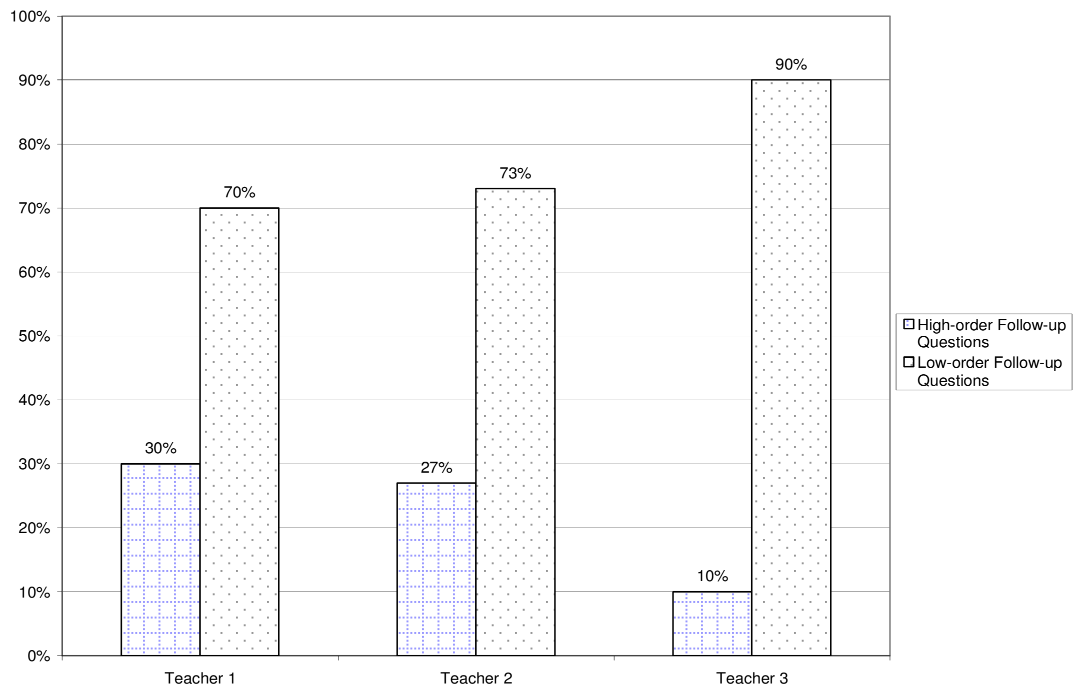

Figure 1. Percentage of follow-up questions that was high and low–order

Type of Instructional Setting

The final variable examined in this study was that of instructional setting within the classroom. Table 6 shows the comparison of instructional setting to the types of questions asked by the teacher. In the small group setting, 74% of the questions asked were low-order and 26% were high-order (see Table 6). When looking at the data for the whole group setting, 95% of the questions were low-order and 5% were high-order (see Table 6). In conclusion, low-order questions were more prevalent in both instructional settings. High-order questions were more frequently found in the small group instructional setting.

Table 6

Comparison of Instructional Setting with Type of Questions Asked

			Instruction type		Total
			s	w	
Question type	low	Count	350	112	462
		Expected Count	369.8	92.2	462.0
		% within Questiontype	75.8%	24.2%	100.0%
		% within instructiontype	74.0%	94.9%	78.2%
		% of Total	59.2%	19.0%	78.2%
	high	Count	123	6	129
		Expected Count	103.2	25.8	129.0
		% within Questiontype	95.3%	4.7%	100.0%
		% within instructiontype	26.0%	5.1%	21.8%
		% of Total	20.8%	1.0%	21.8%
Total		Count	473	118	591
		Expected Count	473.0	118.0	591.0
		% within Questiontype	80.0%	20.0%	100.0%
		% within instructiontype	100.0%	100.0%	100.0%
		% of Total	80.0%	20.0%	100.0%

Note. *s=small group instructional setting; w=whole group instructional setting.*

A chi-square test was run to compare the type of question asked to the instructional setting. The chi-square test revealed that the types of questions asked differ in the type of instructional setting, χ^2 (1, N = 591) =24.221, p <.001 (see Table 7). Therefore, teachers in small group settings ask high-order questions as compared to when they are in whole group settings.

Table 7

Chi-square Test Comparing Type of Questions to Instructional Setting

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	24.221	1	<.001		
Continuity Correction	23.011	1	<.001		
Likelihood Ratio	30.623	1	<.001		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	24.181	1	<.001		
N of Valid Cases	591				

Teacher Behaviors. Another form of interaction between teacher and student can be found through the use of nonverbal communication. This type of communication can be found in behaviors exhibited by the teacher while waiting for students to respond to the question asked. This nonverbal communication became apparent while the researcher was watching the observed teachers. The behaviors were noted in the comments section of the instrument (see Appendix A). The description of behaviors given are to provide a more detailed description of the instructional setting in which the students were present.

Teacher 1 taught in two different contexts: whole group activities and small group activities. During both contexts, teacher 1 used similar techniques while waiting for students to respond. First, teacher 1 gestured by shaking her head up and down, as well as gesture by pointing to items in the problem to focus on. Second, teacher 1 used the technique of reteaching when asking follow-up questions. For example, students were asked "Does the line go through the origin?, Should we connect the dots?, and Where is the independent variable?" When waiting, the teacher maintained eye contact with the students being addressed at all times.

Teacher 2's instruction took place within small group activities. Due to this structure of classroom learning, there were different techniques used that were dependent on the needs of the different groups. For example, one group required the teacher to rephrase the questions being asked. The teacher would ask a question such as "How did they go from this building to the next?" Other groups needed more of the reteaching technique with guided clues. For example, the teacher asked "What is staying constant? and What does five next to the n mean?" The teacher did make eye contact with all groups during their turn for help and shake her head yes when they were on the right track. Likewise, teacher 2 gestured often with her hands. One example of this gesture was the use of her hands to portray a balance.

Finally, teacher 3 used the context of whole group lessons during her instruction. Unlike the first two teachers, who used significant gestures and reteaching during their instruction, teacher 3 spent most of her time stationary looking out over her students. Very little wait time was allowed for students to answer questions. Instead, the teacher's follow up questions consisted of clues to arrive at the answer to each question. Examples included “We use an x and a pause, Do you think the graph will go up or down?, and “What other variable did we use?”

Summary of Results

The main purpose of this chapter was to evaluate how types of questions differed among the three different teachers, as well as examine the differences in wait time allowed after each type of question. In addition, the researcher sought to determine if the instructional setting had any affect on the types of questions asked. The data collected provides valuable information for the discussion of types of questions, wait time, and instructional setting as it relates to communication in the classroom. This discussion can be found in the final chapter of this study.

CHAPTER V

SUMMARY AND CONCLUSIONS

This chapter begins with a brief summary of the results of this study and how they are contextualized to the setting observed and then presents conclusions for each of the research questions. The chapter also includes implications for educators in mathematics classrooms and recommendations for areas of further research.

Summary

The major goal of this study was to provide research that will encourage better communication within the mathematics classroom. Communicating within the classroom is important for assessing students' thinking processes within mathematics education. NCTM (2000) states that "students gain insights into their thinking when they present their methods for solving problems, when they justify their reasoning to a classmate or teacher, or when they formulate a question about something that is puzzling to them" (p.61). In order to study communication within the classroom, the research focused on the teacher and one component within instruction: the art of questioning. The variables within the practice of questioning chosen to study were the types of questions asked, the amount of wait time allowed for students to respond, and the instructional setting of the classroom in whole and small groups.

The results of this study are important for giving educators a basis to implement ideas which will contribute to student's communication of mathematical ideas in the classroom. There were both positive and negative outcomes that will be addressed in the conclusions. On the one hand, this research found sufficient wait time with high-order questions; the teachers observed allowed students adequate time to express their thoughts clearly when asked a high-order question. In addition, follow-up questions were asked more often after a high-order question than a low-order question. The instructional setting differed greatly and affected the type of questions asked and in turn the communication from students. However, similar trends to previous research regarding a higher occurrence of low-order to high-order questions were also found from the data. This trend was also present in the types of follow-up questions that were asked, as a majority of follow-up questions were of the low-order type. A more detailed discussion of these trends is below.

Conclusions

Comparison of High and Low-Order Questions Asked

Communication begins with the type of question asked by the teacher. This study found a much higher occurrence of low-order questions than high-order questions. All three teachers observed accurately depicted the findings of previous research, which states that at least 50% of the questions asked by teachers are low-order questions (Black, 2001; Myhill & Dunkin 2002). After determining the confidence interval regarding Myhi.ll and Dunkin's (2002) research, it was previously noted that all three teachers observed in this study did not fall within the upper and lower limits. Myhill and Dunkin (2002) were unclear about their sample only noting the use of multiple teachers for a total of 54 literacy lessons observed. The study does not reference if these observations were one per teacher or many teachers multiple times. However, this current research looks at repeated measures of three teachers' questioning techniques over a period of time. Thus, it is concluded that the percentage of 64%, as noted specifically by Myhill and Dunkin (2002), may not be representative of all teachers and thus an inaccurate measure of teacher's low-order questioning frequency.

Another interesting finding was the use of the method "checklisting" (Moyer & Milewicz, 2002). Questions such as "What is the independent variable?, What goes on the x axis?, What did you divide from the numerator?, and Is this proportional?" were just a few of the many questions which followed the "checklisting" method. These questions were very direct with an expected answer. Teachers used this method as a procedure to go step by step through the concept at hand. It was very apparent that the teachers' questions were mostly confined to the knowledge and procedural levels of Bloom's taxonomy (Bloom et al., 1956). These questions allowed for very little input from the students, and instead kept most of the control in the hands of the teachers. Teachers were able to get the answers they wanted, but they did not really fully grasp the students' level of understanding nor did they ask a significant number of questions that would foster more communication of their mathematical understanding. As a method to create communication in the classroom, this type of questioning allowed communication to be mostly teacher-directed rather than fostering a teacher to student exchange. It is concluded that all three teachers did more to inhibit communication in the classroom rather than solicit it from their students, based on the fact that the overall majority of questions that were asked in the course of the lessons observed were low-order questions.

Wait Time After High and Low-Order Questions

Wait time differed depending on the type of question asked, with higher-order questions having about a two second higher mean than low-order questions. Previous researchers have noted that wait times of 3 seconds or more are necessary for students to properly be able to formulate a thorough and well-thought out response (Rowe, 1974; Stahl, 1994; Wilen, 2004). This research has found that high-order questions allow this minimum three seconds of wait time. This allowance of wait time supports previous findings which state that students are enabled to formulate their response and participate more in the communication of the classroom, as well as express different solution strategies to a given problem (Henningsen & Stein, 1997). It has been noted that teachers should present information to their students at the same rate in which the students can cognitively process the information (Tobin, 1986, 1987). This study has found that when teachers ask a high-order question of their students, then they have given them ample time to process their response. Thus, one can conclude that high-order questions positively affected communication in the classroom.

While the findings from this data meet the minimum three second wait time for high-order questions, there are other conclusions to be made. The wait time for high-order exceeded the minimum three seconds, to the extent that the findings fell outside the confidence interval upper limit. This research suggests that the three second minimum does represent all types of questions asked. High-order questions require more than the three second minimum and thus should not be classified to that standard. High-order questions are application, evaluation, synthesis, or analysis in nature, and thus require students more time to formulate their response.

Previous studies looking at high-order questions and wait time have found differing results with regards to the three second minimum. Rowe (1974) studied elementary through college level science classrooms and found a mean wait time of one second. Swift (1983) found teachers who had been trained in asking higher-order questions still fell just below the three second minimum goal of wait time. Henningsen and Stein (1997) found teachers to "allow an appropriate amount of time for discussion," but this appropriate amount of time was not defined (p. 540). Edwin (1999) conducted a study among 70 teacher interns who underwent a sixteen week practicum with a focus on asking higher-order questions and allowing sufficient wait time. At the conclusion of the study, the interns were found to ask higher-order questions with an average wait time of 3.6 seconds. However, in Tobin's (1986) study of middle school language arts classrooms higher-order questions yielded a mean of 4.5 seconds. Tobin's findings support the findings in this study that high-order questions require a greater amount of wait time.

These differences in wait times require further consideration of the three second minimum given to all questions asked. The differences found in previous research come from all different types of contexts and settings. Good and Brophy (2003) state that wait time should be suited to the questions being asked and ultimately the goals the questions have been designed to accomplish. The research has shown that the type of content being taught affects the amount of wait time that is allowed. Can what is taught in a science classroom be generalized to what is taught in a mathematics classroom? This research concludes the answer to be no. The three second minimum wait time must not be seen as a minimum in all types of classroom settings. Content must be considered when deciding on the appropriate amount of wait time to allow.

Low-order questions found differing results with regards to wait time. While high-order questions met the recommended minimum three second wait time, low-order questions were found to have a mean less than three seconds. This finding can be attributed to the more divergent nature of the questions being asked. The low-order questions asked allowed very little room for independent thought, and thus found students either responding at a more rapid rate or the teacher speaking sooner, in hopes of guiding the students into the correct answer so that the lesson could proceed.

Follow-up Questions After High and Low-Order Questions

Follow-up questions were asked more often after a high-order question. Follow-up questions aim at probing or guiding the student toward a discovery of a mathematical concept or giving more explanation to their initial response (Kawanka & Stigler, 1999). Questions asked in this study that follow this definition included “How would that change the equation?, Why multiply by four?, Proportional relationships look like what?, How did you know?, and What do you multiply by two?” These questions support the research that has found that follow-up questions guide students toward independent thinking (Sahin & Kulm, 2006).

On the other hand, a closer look at the data for follow-up questions found a much higher percentage of the follow-up questions being of the low-order type rather than the high-order type. This causes some concern regarding the previous findings. The most notable concern is the alignment of these findings with those of previous research, which found mathematics classrooms asking students to redefine already known procedures rather than their own independent thoughts (Kawanaka & Stigler, 1999). With the goal of this research looking towards finding ways to get students to communicate in the classroom, it has already been determined that low-order questions do not encourage this result. Thus, this research has been found to replicate previous studies, which have mixed findings between a positive relationship among follow-up questions and student learning and a negative relationship between follow-up questions and student learning (Wright & Nuthall, 2002; Hughes, 1971). While the follow-up questions did probe at the students' thoughts, more often than not the communication encouraged was a simple, direct response.

The final conclusions to be made regarding the follow-up questions asked were the similarities found to the original questions asked. All three teachers were found to have similar trends regarding the types of questions they asked, no matter if it was the original question or a follow-up question. Each teacher's classification of follow-up questions as either high or low-order was within 5% of the classification of their original question as high or low-order. For example, teacher 2 had a 76% to 24% low- to high order occurrence of the original question and 73% to 27% low- to high-order follow-up questions. While this still does not support the idea of communication in the classroom, it is interesting to note the consistency of the questions they asked. Whether it was an original question or a follow-up question, low-order questions were more likely to be asked.

Instructional Setting Influence on the Types of Questions Asked

Small group instructional settings produced more questions asked than whole group instructional settings. Small group instruction not only allowed a higher number of questions, but also yielded almost all of the high-order questions. This is supported by the observed lessons of teachers 1 and 2. Placing children in small groups enabled these teachers to move around from group to group and assess students' needs and progress based on the type of student response given. This form of assessment allowed those teachers to ask more detailed and direct questions in order to gain insight into student understanding of the concept being presented. Within the groups themselves there was also an increase in confidence and motivation, because students were able to communicate with one another and share their strategies for finding a solution. These positive effects correspond to the findings of Cnop and Grandsard (1998) and Depree (1998), who reported increases in motivation and confidence among students in the small group setting. Small group instruction was very beneficial in creating communication of mathematical ideas within the classroom.

In contrast, teacher 3 did most of her questioning through whole group lessons and asked mostly procedural questions that required brief one to two word answers. She very much followed the description given by Evans (2000), which defines this type of setting as having a teacher take on the role of lecturer and sole provider of information in the classroom. Students were very passive and given very few opportunities to expand upon their thinking related to the task at hand. This supports previous research done by Myhill (2006), which found whole group settings to offer very limited opportunities for students to talk about their thinking and learning in the classroom. Whole group lessons were not a beneficial setting for communication of mathematical ideas in the observed classrooms.

A second aspect within the instructional setting was the behaviors exhibited by the teachers to further encourage or not encourage students to respond. Once again, teachers 1 and 2 had very similar behaviors compared to teacher 3. Teachers 1 and 2 both maintained eye contact with the students and gestured in manners to encourage students to communicate. Teacher 1 used lots of head nodding and rephrasing of the question, while teacher 2 gestured with her hands and rephrased questions. The gesturing and body language used encouraged students to not only respond to the question being asked, but also imparted the notion that their responses were important and valued in the classroom discussion. Teachers 1 and 2 both used behaviors that positively impacted the communication of mathematical ideas in the classroom.

This combination of small group setting and teacher behaviors provides a very important line of thought when considering how to get students to communicate their thoughts in the mathematical classroom. Asking a question may not be enough to make the student feel comfortable sharing his/her thoughts. Often, students may need a more relaxed setting with extra bits of encouragement to feel safe enough to share their thinking. This is easily accomplished through using small groups, where students have more freedom to bounce ideas off one another without fear of embarrassment in front of the whole class. In addition, the teacher is better able to become the facilitator of communication rather than the sole provider of knowledge. This combination allows the teacher more opportunities to exhibit the roles of creator, listener, and responder. The luxury for the teacher is the ability to become a listener and responder first, and then follow the students thought toward to create more in-depth questions.

Recommendations

This study focused on the role of the teacher in eliciting communication in the mathematics classroom. Most often the learning process begins with the teacher, but is does not have to end with the teacher. Although the teacher plays a significant role in this process, it would be interesting to explore how the students actually respond to the teacher's lead. Do their responses relate to the questions being asked? Do the teacher's questions cause students to formulate their own questions and thus create a more two-way communication? If students asked questions of their own, are they high-order or low-order in nature? The first recommendation of this study would be further research that focuses on learning from the student's perspective.

A second recommendation would be further training of teachers in the implementation of small group instruction within the classroom. The most positive results from this study were found when students were placed in small group settings. If teachers knew how to plan lessons structured around activities that encouraged their students to work together, then would they be more likely to implement this kind of setting in the classroom? Are teachers afraid that the amount of content learned would be inhibited if students were asked to discover the concepts with their peers? Does the resistance to small group instruction stem from lack of knowledge in how to implement it, or fear of not being in total control of the learning of their students?

Finding ways to not only foster deeper mathematical understanding but also critical thinking skills is a necessity in the world of education. Communication is just one way to attain these goals for each student. This study hopes to have provided a method to educators which will encourage them to get their students talking about mathematical concepts. Through the use of high-order questions, a minimum of three seconds wait time, and an instructional setting that encourages interaction in the classroom, this goal of communication can be met in every mathematics classroom.

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APPENDIX A

Teacher Questioning Components Instrument

Question #		Type of Question	Amount of Wait Time	Follow Up	Comment
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
Total					

Codes for Recording:

L/H=Low-order question/High-order question
Y/N-Yes/No

APPENDIX B

Questions Coded for Reliability Test

Teacher 1 Questions

1. If you know the height of 3 hexagons, can you figure out the height of 6? ________
2. That works because it is? _________
3. Could we make an equation for this? ____________
4. Does that equation look like this one? _____________
5. Does it have a constant unit rate? ___________
6. What does the graph look like? _____________
7. How could we do it? _________________
8. How do we get to stat plot? ____________
9. What are we going to do on this? ____________
10. We want the x to come from where? _____________
11. Where should the y axis come from? _____________
12. What if we go look at the graph? _____________
13. Why, what is happening here? _______________
14. How do we do that? ____________
15. What is the smallest x? ___________
16. What is the biggest x we want to look at? __________
17. What do we want to count by? ____________
18. We want to go 0 to how big? __________
19. How can we check it out? ______________
20. Does that look like a straight line through the origin? __________

Teacher 2 Questions

1. How many did I count for this one? __________
2. Could I count 3 for this one? ____________
3. What would I have to add? ____________
4. What would I do for this one? __________
5. How many would it be altogether? __________
6. How did you get 14? ________________
7. Where is the 3 coming from? ___________
8. How many did we say this was? __________
9. Why are you saying we are adding 3 for this one? __________
10. On this one I had how many? _______________
11. If I add 4, then how many should it be? ______________
12. Why am I not adding 4? ___________
13. Can I just do 3? ____________

14. Why is it I'm just adding 3 for each cube? __________
15. How are you figuring this out? ________________
16. Why is it 3 faces? ___________________
17. Can I break down the 3? ______________
18. What are those? ________________
19. Do those ever change, do the numbers ever change? _________
20. For each what am I adding 3? _____________

Teacher 3 Questions

1. After 1 hour, how many had ridden? _______________
2. What if I told you 10 hours, what would you do to figure it out? ____________
3. Tell me how you figured that out? (How did you know in your head what to do?) _____________
4. Could we put this information on a graph? ____________
5. What do you think the graph would look like? Would it go up or down? __________
6. Why do you think it would be going up? ____________
7. Where should I put time? ________________
8. Why should I put it on the bottom? _______________
9. What did we measure time in? ________________
10. Where should 0 go? ___________
11. Do you think it is important that I draw all my spaces equal? ____________
12. For 2 hours, what do I go up to? _________________
13. What shape do we have? _________________
14. If I have 0 hours, then how many riders? ______________
15. How would we do that? _____________________
16. In half an hour, how many will ride? ________________
17. By looking at the graph, can we decide how many people have ridden? __________
18. If I knew how many had ridden, could I figure out how many hours they had been open? _____________
19. What equation did we use to graph the line? __________________
20. What if I didn't know x, but knew y, could I figure it out? ______________

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