Oral Mathematics in the Teaching and Learning of Mathematics: A Study on the Impact of Oral Mathematics Drill Activities on Grade 9 Students' Learning of Mathematics

by

Katarina Schilling

A Thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

in partial fulfilment of the requirements of the degree of

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Department of Curriculum, Teaching and Learning

University of Manitoba

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ABSTRACT

This study is an analysis of the impact of researcher designed Oral Mathematics drill activities on Grade 9 (Senior 1) students' learning of mathematics. A mixed method research design was employed in order to examine the Grade 9 student volunteers' ability to produce automatic responses to various mathematics questions after exposure to researcher designed Oral Mathematics drill activities.

The findings revealed that students were able to produce automatic responses in a number of areas of mathematics after a certain amount of rehearsal using Oral Mathematics drill activities.

The study provides mathematics teachers and resource teachers with information on how to design and implement their own Oral Mathematics drill activities that meet their students' learning needs. It also provides teachers with an effective yet inexpensive approach to teaching mathematics and assessing learning of mathematics.

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Thanks to my teachers, whose great abilities to teach inspired me to follow in their footsteps.

Thanks to all my students, who inspired me to look for new ways of teaching.

Last but not least a heartwarming thanks to my husband, Reinhard Schilling, and my sons, Peter and David, whose love and patience made this thesis writing possible.

DEDICATION

To my wonderful and loving children – my daughter, Izabella, who will always remain in my heart, and my sons, Peter and David, who give me such joy and purpose.

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ORAL MATHEMATICS AND THE TEACHING AND LEARNING OF MATHEMATICS

Introduction

I believe that mathematics teaching and learning is an interactive process between teachers and learners. In order for mathematics learning to take place at least two requirements are necessary. The first requirement is that the learners need to be interested in learning mathematics. A second, and equally important requirement, is that the teachers need to make mathematics learning slightly challenging to the learners by continuously assessing the accuracy of the learners' replies as well as the ease with which the learners provide those replies. Without a challenge learners may eventually get bored; yet, with too much challenge, they may get frustrated not only with the process of learning but also with the subject area itself.

Oral mathematics is a great tool for teachers to use in their classroom in order to add small daily challenges in mathematics learning for all their students. The reason why I believe so strongly in the importance of Oral Mathematics is due to my own experience as an elementary school child many years ago. A type of experience that left a great impression on me happened during the summer vacations while visiting relatives. One of my uncles, the jovial uncle Feri, took a great pleasure in asking us children mathematics questions. Each day when my cousins and I were playing together, Uncle Feri would say: "Let's see how well you know the times table." Then he would quickly ask: "What is 6 times 7?" And then, "What is 7 times 6?" Uncle Feri always expected a quick reply; if we were not fast enough, he would laughingly provide the answer. After a few math questions he would end the math game by saying: "We need to leave some fun for tomorrow too." By the end of that summer vacation we were masters in providing quick and correct replies to the times table questions. The following summer Uncle Feri noticed that we could still reply quickly to the times table questions, so he asked us questions like: "What is 500 plus 600?" or "What is 7000 take away 3000?" Answering math questions daily might not be a child's expectation for a summer vacation, but those few minutes of Oral Math questions each day left me with a positive and memorable experience that I cherish to this day and now try to share with others through my Oral Mathematics drill activities.

In this age of advanced technology, the knowledge and use of mathematics, both in and outside of the mathematics classroom, is becoming more important; yet, many students are unable to use mathematics outside the classroom context (Boaler, 1998). My personal experiences working with elementary and secondary school students both as a schoolteacher and as a tutor affirm Boaler's claim. Furthermore, "mathematical knowledge is cumulative: a child who misses a step in the development of a concept cannot go on" (Mighton, 2003, p. 20). The ability of students to do well in mathematics relies on their understanding of previously learned material (MECY, 2008; Van de Walle & Folk, 2008) as well as their retention of it (Mighton, 2003). For this reason, I have been trying over the years to develop ways of helping students become more successful mathematics learners. The research study presented in this thesis is part of that effort. This thesis is a report of a mixed method, three-month long study of mathematics learning conducted in an urban senior high school with five Grade 9 (Senior 1) students. Daily exposure to researcher designed Oral Mathematics drill activities showed that it was possible to cause automaticity in student replies to mathematics questions which were based on the concepts of the Grade 8 Manitoba curriculum outcomes not just on basic facts. The results of the study were based on data collected through researcher-designed tests, surveys, daily quizzes and the researcher's field notes. Chapter 1 of the thesis presents the problem statement, the background of the study, and the significance of the study for teaching and learning mathematics. Chapter 2 presents a discussion of the literature relevant to this study. Chapter 3 describes the research method used in the study. Chapter 4 presents and discusses the quantitative data collected in this study. Chapter 5 presents and discusses the qualitative data collected in the study. Chapter 6 presents the conclusions drawn from the findings of the study.

Oral Mathematics: What is it?

Oral as defined by *Webster's New Collegiate Dictionary* (1979) means "uttered by the mouth or in words: spoken" (p. 800). Speaking is a natural human activity. Children learn to communicate with those around them by learning to use the spoken language of their caregivers. 'Oral mathematics' then could simply mean mathematics expressed vocally rather than in a written form. This definition, which could include many types of math activities, is very broad and, therefore, must be made more specific. From this point forward, I will capitalize the phrase, 'Oral Mathematics', to indicate that I use it with the specific meaning provided below.

Oral Mathematics is not a discussion about mathematics during math class. It is not simply listening to a mathematics teacher who is presenting a lesson to a class full of students. Oral Mathematics is not a simple regurgitation of facts, rules or procedures without understanding. In addition, Oral Mathematics does not employ the aid of a calculator or any kind of object for manipulation or written calculation. Although all of the above-mentioned ideas may be useful in mathematics learning, none define Oral Mathematics.

In this study, 'Oral Mathematics' refers to rapid spoken mental math activities like the ones I mentioned in the introduction. It is a variety of short and quick mental math activity sessions during which both the mathematical questions and answers are presented orally (by vocalization) rather than in writing. It is very important to note that these mental math activity sessions are short in duration; ideally 5 minutes in length but definitely no more than 10 minutes per session. Although they are incorporated into math lessons, Oral Mathematics activities are never the sole mathematics lesson of the day. It is equally important to note that the mental math activity sessions are fast paced, requiring students to reply rapidly. In Oral Mathematics there is no time for lengthy periods of thinking and slowly figuring out the answer to a question. Oral Mathematics activities are short, quick math drills based on previously learned material that requires students to rely on their existing mathematical knowledge. Oral Mathematics activities must always be based on concepts for which students have developed an understanding but cannot yet retrieve facts linked to this understanding quickly. For example, a primary school student might understand that adding two numbers means combining them together to form one bigger number, or adding two sets means combining them into one bigger set. This same student might also be able to figure out correctly any number of addition questions with the aid of manipulative objects, but might be incapable or slow in figuring out the answers in his or her head. Drills that encourage students to think and say the answer out loud may incidentally aid them in quickly retrieving the concepts which they already understand when these concepts are needed.

Not only is it important that students remember basic facts and are able to do quick mental calculations, it is equally useful that adults be able to perform simple mental calculations as part of their daily activities. The ability, while shopping, to quickly calculate mentally or estimate how much a few grocery items will cost will help us to know whether we can pay for all the items we intend to get. I believe that schools need to place a greater emphasis on mental mathematics by using Oral Mathematics drill activities right from the start in primary grades; "because figuring in our heads is such an important life skill, it should have a regular role in your classroom math teaching" (Burns, 2007 p. 51). Students need to know their arithmetic facts well so that they can use those facts with ease when performing mental or pencil and paper calculations. I strongly believe that basic fact mastery, as John Van de Walle and Folk (2008) state, "is not really new mathematics; rather, it is the development of fluency with ideas that have already been learned" (p. 167). Furthermore, I fully agree with their statement that, "although students who do not have a command of the basic facts can make use of calculators and tedious counting, relying on these methods for simple number combinations is a serious handicap to mathematical growth" (p. 167).

Oral Mathematics drill activities are not restricted to elementary school classes. High-school students also have a need for better mental calculations, and they, too, can benefit from daily Oral Mathematics drill activities. Using drill or rehearsal to reinforce and to commit to memory, or retrieve from memory, material that has been already learned is very important (Bruning, Schraw, Norby & Ronning, 2004), because it allows students to attend to new patterns, relations, and principles in mathematics without being distracted by a lack of proficiency with the simpler material and the basic facts involved. I also believe that drill activities need to be carefully designed with a specific purpose in mind in order to most benefit students (Van de Walle and Folk, 2008).

Activities to be used as drills for Oral Mathematics vary according to grade level. For example, after teaching several lessons on addition or subtraction, a Grade 1 or Grade 2 teacher might spend five minutes at the start of each mathematics class reinforcing that knowledge by asking students to reply orally to a few basic addition or subtraction questions such as $4 + 5 = \_$ (9), or $8 - 3 = \_$ (5). This can be done by simply asking the questions without a visual aid or by presenting the questions on the chalkboard or by using an overhead projector.

At a Grade 5 or Grade 6 level a teacher might use Oral Mathematics to reinforce students' knowledge of fractions. An activity for practicing halves might look like the following example: one half of 6, 60, 600 (3, 30, 300; a simple activity); or one half of 30, 300, 3000 (15, 150, 1500; a little more difficult); or one half of 250, 2500, 25000 (125, 1250, 12500; even more challenging).

Similarly, at a Grade eight level a teacher might ask students to reply orally to a few simple mathematical questions at the start of each mathematics class to reinforce their knowledge of decimals or percentages. Examples of these simple questions include: What is 10% of 30, 50, 70? (3, 5, 7); What is 20% of 30, 50, 70? (6, 10, 14); What is 30% of 30, 50, 70? (9, 15, 21).

Keeping in mind that Oral Mathematics questions need to be short and simple, at the high-school level the questions can take the following form: "What is the complementary angle of a 70 degree angle?" (20°); "Which quadrant does the point (-5, 2) lie in?" (quadrant II); "What is the slope of the line y = - 2 x ?" (the slope is -2); or "What is the y-intercept of the line y = 3 x + 5 ?" (the y-intercept is +5).

The beauty of Oral Mathematics is that the teacher can immediately assess and correct, if need be, every response, thereby reinforcing the correct response. As described above, Oral Mathematics drill activities can be designed for any grade level. They can be made to be as simple or as challenging as the students need them to be and therefore can be useful for the whole class. At any grade level the challenge is to create drill activities which students enjoy and which are at the same time good teaching tools.

Oral Mathematics and Auditory Memory

The purpose of Oral Mathematics is to enhance mathematical memory and to trigger quicker mathematical thinking. When studying mathematics, students need to develop mechanisms which will help them to remember what they have learned and which also will help them to retrieve that knowledge at a later time. The short term, working memory has a very limited capacity and helps retain information while a problem is being worked out, but it is impermanent and cannot hold information for long (Bonds-Raake and Raake, 2003). The long-term memory, on the other hand, is permanent and can hold an unlimited amount of information (Bonds-Raake & Raake, 2003).

The auditory memory according to the *APA Dictionary of Psychology* (VandenBos, 2007, p. 87) is "the type of memory that retains information obtained by hearing. Auditory memory may be either short-term memory or long-term memory, and the material retained may be linguistic (e.g., words) or nonlinguistic (e.g., music)."

A non-mathematical but, nevertheless, practical example of the relationship between oral learning and auditory memory is presented to us when we are introduced to someone for the very first time. We hear the person's name when being introduced, but unless that name is dear to us or is very unusual, most of us will forget it shortly after we have heard it. On the other hand, if we repeat the name out loud right after we hear it being said, and say it out loud a few more times while we are talking to that person, it is more likely that we will have that name committed to memory. I believe that the ways we commit a person's name and simple mathematical facts to memory are most likely the same or at least very similar; that is to say, we need rehearsal in order to retain information in long-term memory (Bonds-Raake & Raake, 2003). For example, in a Grade 1 class, the teacher hands out a worksheet with simple basic fact questions like 3 + 4 = __ (7), and the students calculate the answers and write them down. Some students might commit the arithmetic fact to memory, but many will not. Lack of ability to retrieve facts instantly or automatically is likely to cause students difficulties with more complex math questions (Cumming & Elkins, 1999; Poncy, Skinner & Jaspers, 2007; Woodward, 2006). If instead of handing out a worksheet full of questions, we can imagine the teacher asking one question at a time orally and perhaps placing the question on the board or overhead projector. The students, after figuring out the answer to the question, would call out the answer (7 in our example) and then say the complete algebraic statement out loud: $3 + 4 = 7$. This method may increase the chance that the math fact will be committed to memory. The above example of the relationship between oral learning and auditory memory, I believe, is a good illustration of the relationship between oral mathematics and auditory memory. Research studies such as those by Chaffin and Imreh (2002), Cumming and Elkins (1999), Freeze (2007), Poncy, Skinner and Jaspers (2007); and Woodward (2006) point the reader to the importance of automatic retrieval or automaticity.

Oral Mathematics uses the power of auditory memory. Students' ability to solve mathematical problems heavily relies on their ability to recall: (a) basic facts of addition, subtraction, multiplication and division, (b) rules on how to perform the four operations (addition, subtraction, multiplication and division) not only on whole numbers but also on fractions and decimals, (c) pattern building, (d) other mathematical rules and concepts such as orders of operation, ratios, percents, perfect squares, square roots of perfect squares, estimation, comparison of numbers (>, <, =), (e) recognizing certain geometric shapes such as regular and irregular polygons (triangles, quadrilaterals, pentagons, hexagons), and (f) calculating the perimeter and area of regular and irregular shapes (triangles, quadrilaterals, pentagons, hexagons) (MECY, 2008). Teachers need to help students develop this ability to recall by drawing on different ways of human learning.

When students write in their notebooks "$2 \times 5 = 10$" as well as say out loud "two times five is ten" or "two times five equals ten", they then increase the chance of them remembering the equation. By writing down the equation, students are using motor learning; when they are looking at the equation, they are using visual learning; as they are saying it out loud, they are using oral learning; and as they hear themselves say the equation out loud, they are using auditory learning. I believe that by presenting students with a variety of forms of learning (motor, visual, oral, and auditory) teachers increase the chances of helping more students to learn (in this case, mathematics, but this may also be applicable to other subject areas).

Although some students find learning easy, many students have at least some difficulty doing mental and written calculations. Improving their ability to recall information quickly and accurately may lead to more success in mental calculations as well as written calculations. I propose Oral Mathematics as a way of helping students to recall relevant mathematical information by using the power of their auditory memory.

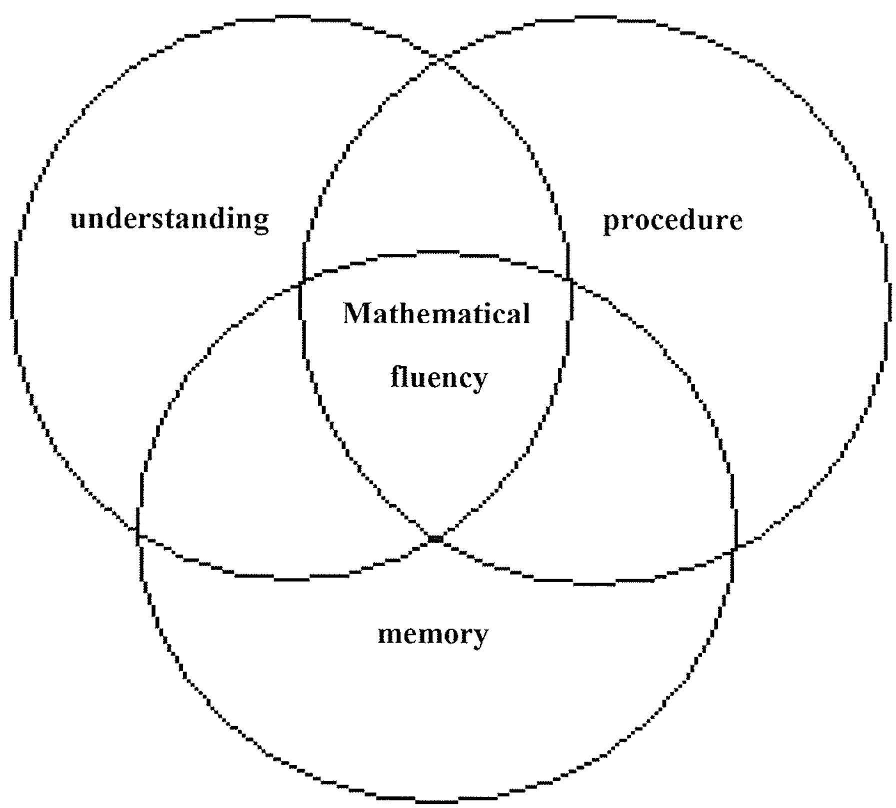
Oral Mathematics and Mathematics Teaching and Learning

Over the years, students have been taught to learn mathematics by doing numerous written math exercises using pencil and paper as well as using manipulatives such as rods and blocks. Although many students benefited from those methods, there were still many other students who struggled in the mathematics class.

Lee and Olszewski-Kubilius (2006) have noticed that while some gifted students may prefer to learn on their own, many students, especially the non-gifted, prefer auditory modes of learning. Since I believe that every student has the right to learn, we must explore and determine the modes of learning that will aid each student most. Perhaps exposing students to multiple modes would be most beneficial, since that way we would be engaging more students in the modes suitable to them. Struggling students may need "seeing" and "doing" as well as the combination of "listening" and "speaking" for their learning success. If this hypothesis is true, then struggling mathematics students may need exposure to oral and auditory work in order to be able to learn. This is where Oral Mathematics comes in.

Mathematics learning is a complex process. The learner needs to understand the mathematical concept, which he or she is intending to learn (conceptual learning). He or she then needs to learn the process involved in learning the concept and in obtaining a solution (procedural learning). Finally the learner needs, I believe, to commit to memory as well as be able to retrieve from memory all that he or she has understood and practiced. This final stage is where I believe Oral Mathematics fits into the big picture of mathematics teaching and learning (see Figure 1-1).

Figure 1-1. My visualization of mathematical learning and fluency



In my opinion, learning mathematics is similar to learning a foreign language or learning to play a musical instrument. Learning the content presented in a new lesson requires retrieval of previous knowledge. In order to retrieve previous knowledge, it had to have been previously committed to memory.

Some students know how to do quick and accurate mental calculations and to retrieve information necessary for their calculations. Other students need to be taught to do quick and accurate mental calculations. They also need to be helped to commit information to memory and to retrieve it when needed. Building auditory memory through Oral Mathematics is a method of helping students to memorize and retrieve information.

Oral Mathematics is a small part of mathematics teaching and learning. The ability of students to perform quick mental calculations is essential if they are to succeed in their study of mathematics. The National Council of Teachers of Mathematics' (NCTM) *Curriculum and Evaluation Standards for School Mathematics* states that "fostering the use of a wide variety of computation and estimation techniques-ranging from quick mental calculation to those using computers-suited to different mathematical settings" need to be included in the teaching of computation (NCTM, 1989, p. 95).

More specifically, Oral Mathematics is a part of mathematics we know as mental mathematics. The exclusive use of the human brain while performing mathematical calculations without the aid of calculators, abacus, pencil and paper or any manipulative is part of the definition of both oral and mental mathematics. The difference in the two lies in the speed of the process and in the types of activities.

The importance of mental calculation has been recognized by mathematics educators, as explained in the following statement: "Students should possess adequate mental arithmetic skills so that they are not dependent on calculators to do simple computations and are able to detect unreasonable answers when using calculators to solve harder computations." (NCTM, 1989, p. 96)

Although today most people have access to a calculator, mental calculations did not and cannot be replaced by calculators. Mental calculations are performed by people in various simple daily activities either because a calculator or a pen and pencil are not available or because it is faster and easier to compute many everyday mathematical problems using mental calculation than using a calculator or writing it on a piece of paper (Burns, 2007; Rubenstein, 2001). Therefore, learning to perform mental calculations is an important part of mathematics learning.

Mathematics is a necessary part of our daily living. We use mathematics when we do our income tax returns, when we calculate the exact measurements in doubling or tripling our favorite cookie recipe, and when we figure out the right coin combination for the bus fare. Lack of adequate knowledge of mathematics will limit the type of jobs one can be hired to do. The *Common Curriculum Framework* notes the importance of mathematics in today's world, by stating, "A greater proficiency in using mathematics increases the opportunities available to individuals. Students need to become mathematically literate in order to explore problem-solving situations, accommodate changing conditions and actively create new knowledge in striving for self-fulfillment" (Western Canadian Protocol, 1996, p.3).

Solving mathematical problems accurately and efficiently is what the Western Canadian Protocol (1996) and the Western and Northern Canadian Protocol (2006) state as desired learning outcomes for students to attain if they are to be proficient in mathematics. This is what Oral Mathematics drills are intended to promote. In Figure 1-1 (page 12), my visualization of mathematical learning and fluency, I would place Oral Mathematics in the mathematical fluency section, because Oral Mathematics incorporates understanding of concepts, learning of procedures, and memorization of concepts and processes.

Classroom work, homework, and tests and quizzes are all part of mathematics teaching and learning. Teachers assign classroom exercises so they can check students' ability to use their newly learned knowledge while available to answer questions if needed. Homework is usually assigned to give students an opportunity to do work independently of their teacher. Tests and quizzes allow the teachers and the students to see if the new material has been learned well enough so that it can be used to solve problems in a timely way. The goal of Oral Mathematics drills is to improve students' mathematical performance in class work, homework, on quizzes and tests as well as on their out of school mathematics calculations.

As stated earlier, mathematics teaching and learning has gone through many changes, and it will continue to change as society and the needs of society change. Mathematics was taught through memorization of facts and rules, and through the memorization and practice of procedures. It was also taught through manipulation of objects for the purpose of creating conceptual understanding. Throughout the years students listened as teachers explained, they completed worksheets, manipulated objects and, more recently, talked about and wrote about mathematics. Many pieces of the mathematical learning puzzle have been discovered, lost, rediscovered and used over the years. Nevertheless, one piece of mathematical learning is still missing! That piece is seeing things quickly. The instant recall and transfer of knowledge from a simple to a more difficult math question is a valuable ability that can be learned by using drill activities. Not just any kind of drill activities but *oral* drill activities.

Oral Mathematics, which is part of mental mathematics, is one small yet very important part of basic mathematics. Instant recall, for example, which Oral Mathematics aims to enhance, is a valuable ability to have, yet many students seem to be lacking it. Lack of instant recall of basic facts can become a handicap for students if not remedied.

However, teachers do not need to send home the facts sheets to be memorized. Like Williamson (2007) has suggested, we can attempt to improve students' ability of rapid recall by designing activities for mental math.

Pattern and sequences are imbedded in mathematics school curricula. Oral Mathematics can be thought of as a pattern building technique; a knowledge transfer from very simple to more difficult activities. For example, 2×4 can be expanded into 2×40, 2×400, 2×4000 … and as far as the teacher wishes to expand it. When this pattern building exercise is carried out orally, the student not only senses the pattern but receives an instant response as to the correctness to his or her answer, and may receive a correction if necessary. This type of pattern building exercise is useful not only in the elementary grades but also in secondary school.

At a secondary school level a teacher can start with an example such as 50% of 60 and then can expand it into 50% of 600, 50% of 6000 and further, using very large numbers. Also, the teacher can start with the same number and expand the pattern in the opposite direction: 50% of 6, 50% of 0.6, 50% of 0.06 and further, using smaller and smaller increments.

If this pattern building is done as a written exercise, the student might make mistakes and not even be aware of them, but if it is done as an oral exercise, the correctness of the reply is assessed instantaneously.

In mathematics, as in reading, students need to develop fluency. The NCTM Standards document defines computational fluency as "having and using efficient and accurate methods for computing" (NCTM, 1989, p. 32). The methods can vary as long as they produce quick, accurate results, and the students using them are able to explain their method, while realizing that other equally good methods exist.

It is important that students are aware when they make mistakes in their calculations, and it is equally important that they learn to do calculations correctly. Researchers such as Hindy (2003), and Wicket, Kharas and Burns (2002) developed and used strategies that allow students to instantly correct themselves if they made a mistake. The Oral Mathematics drill activities which I have developed in this study are strategies that allow students to be aware of their mistakes and to allow them to learn to produce correct calculations.

Since mathematics learning involves a continuous process of building mathematical knowledge upon previous mathematical knowledge, it can be compared to building a brick wall. Each layer of bricks is built on a previous layer of bricks. How well the wall stands depends on each layer of bricks, not just the last layer. In comparison, how well students do on their Grade 12 mathematics examination depends on how well they learned their mathematics in all the previous grades. Their exam mark will not simply be the result of their Grade-12 mathematics learning.

As previously stated, mathematics learning is cumulative. Therefore, it is important that students form a good foundation at the beginning of their formal education in the primary grades. This is probably best achieved by using a variety of learning methods. It is also important that students continue to increase their knowledge level year after year. Oral Mathematics can serve as a vehicle to enhance students' mathematical learning by providing daily exposure to and rehearsal of (with the purpose of automatization): (a) concepts and (b) procedures from prior grades in a fast, organized and efficient manner.

The Research Question

I believe the ultimate goal of every mathematics teacher is to see his or her students become capable of solving mathematics problems of all types on their own and with ease, starting from simple calculations, such as figuring out the solution for 17 + 18 = (35), to more elaborate word problems (e.g., routine problems, non-routine problems and everyday life problems). Understanding mathematical concepts, performing mathematical processes fluently, and having a quick and accurate recall of basic arithmetic facts and procedures are all necessary parts of the ability to solve problems. Students need to have a variety of methods which aid them in learning and in understanding mathematics. Many educators, such as Baron (2004a, 2004b, 2004c, 2004d), Burns (2007), Mighton (2003, 2007) and Wright, Martland Stafford and Stanger (2002) believe that a step-by-step method of learning mathematics is important not only for learning procedures but also for developing an understanding of concepts.

Oral mathematics is a relatively unknown method of mathematics teaching and learning in our schools, but as Carraher, Carraher, and Schliemann (1987) stated, “teachers may profit from being acquainted with these procedures” (p. 96). In the previous section I argued for the important role that Oral Mathematics can play in the teaching and learning of mathematics. My research study will contribute to this argument by inquiring into the actual impact that the use of Oral Mathematics drill activities will have on students’ learning of mathematics. The research question for the study is: *Can Oral Mathematics drill activities involving the understanding of mathematics concepts (and not just basic facts) be designed and implemented in a way that increases accuracy and speed to the point of developing automaticity?*

In this chapter I have described my beliefs about mathematics teaching and learning and in particular about Oral Mathematics. The topic of Oral Mathematics can be better understood if we also understand the relevant issues surrounding Oral Mathematics: conceptual understanding, procedural fluency, auditory memory, mental mathematics, and knowledge transfer. In the next chapter, I will explore those concepts by discussing the relevant literature.

CHAPTER 2:

LITERATURE REVIEW

The relevant issues surrounding Oral Mathematics that have been addressed in the education literature are reviewed in this chapter. These issues are conceptual understanding, procedural fluency, auditory memory, mental mathematics, and knowledge transfer. First, the literature that describes conceptual understanding is reviewed, since Oral Mathematics is based on mathematical concepts previously understood by the students. Second, the literature that talks about procedural fluency will be reviewed, because in order for students to be able to reply correctly and quickly to a question, they need to be well versed in the required procedures related to solving that particular question. Third, the literature that describes auditory memory will be reviewed, since the concepts that need to be remembered are practiced through oral drill. Fourth, the literature regarding mental mathematics will be reviewed, since Oral Mathematics is a part of mental mathematics. Fifth, the literature concerning knowledge transfer is reviewed, because the whole purpose of Oral Mathematics is to aid students in their mathematics learning so they can use it in and out of school.

Conceptual Understanding

Current Research

A considerable amount of current research focuses on how students learn mathematics. This has led to an interesting discovery, which mathematics teachers probably have known for a long time. Over the years many researchers, (Boaler, 1998; Carpenter, Franke, Jacobs, Fennema & Empson, 1997; Cobb, Boufi, McCain & Whitenack, 1997; Thompsom & Rubenstein, 2000) have found that conceptual understanding plays an important role in mathematics learning. "Today it is vital that young people understand the mathematics they are learning" (NRC 2001, p.16). Conceptual understanding is one of the five interwoven and interdependent strands of mathematical proficiency as seen by the National Research Council (2001). Isolated pieces of knowledge that are not understood are not of much value to students. In fact, they may cause confusion, require more effort when solving a problem, and lead to frustration. The ability to connect a variety of mathematical concepts by seeing the similarities and differences in them makes mathematics learning less stressful and more enjoyable.

Although it is possible to learn simply by memorization or by following a procedure, often this knowledge is forgotten easily when there is little or no understanding of the concept, that lies behind the procedure. When students analyze the procedure until they derive meaning from it, they end up gaining an understanding of the concept and, therefore, better remember the procedure (Skemp, 1978; NRC, 2001; Van de Walle & Folk, 2008). The National Research Council (2001) noted that, "Conceptual understanding is the basis for further conceptual understanding: Knowledge that has been learned with understanding provides the basis for generating new knowledge and for solving new and unfamiliar problems" (p. 119).

Boaler (1997) found that students who understood mathematical concepts were able to adapt their learning to new situations. These students would use logical reasoning when thinking about the strategies or methods to use in order to solve new and unfamiliar problems; they achieved higher scores, and did better on the state-mandated standards test. In her 1998 research paper, Boaler stated that "students who learned mathematics in an open, project-based environment developed a conceptual understanding that provided them with advantages in a range of assessments and situations" (p.41).

Carpenter, Franke, Jacobs, Fennema, and Empson (1997) report that "although there are alternative perspectives, most current theoretical arguments support the development of conceptual knowledge before students master algorithmic procedures" (p. 5). After having conducted a three-year longitudinal study of the development of children's conceptual understanding of multi-digit numerals and operations, Carpenter and colleagues (1997) concluded that their evidence suggested a close link between children's invented strategies and their conceptual understanding. They further stated that children who used an invented strategy, demonstrated understanding for the concept before those children who were first taught the algorithm. Furthermore, they argued that those children who were taught algorithms first, had the limitation that they were unable to use procedures flexibly to solve the extension problems. The NRC (2001) supports the previous statement.

Lo and Watanabe (1997) found that teachers can help their students to improve their understanding in any topic area by providing them with mathematically rich activities. "Most important, students need to have more experience with tasks involving geometry and measurement, because both provide rich contexts for developing concepts of numbers and operations at all grade levels" (p. 234).

Prior Knowledge

Mathematical learning, although cumulative, is not linear. Kieren, Pirie and Calvert (1999) write that "growth in understanding for a person occurs in many ways" (p 212). They suggest that when teaching new material, teachers need to provide students with proper "scaffoldings" and often help them "fold back" to prior knowledge or understanding of simpler concepts or simpler presentations of a specific concept (Kieren, Pirie & Calvert, 1999).

John Mighton (2007) maintains that prior to teaching new material teachers must ensure that the students have the required background knowledge. If students do not have the required background knowledge, teachers should spend the time teaching the missing information before they go on to the new lesson. For example, he states that before learning long division, students "must have some method of finding the answer to simple division questions such as 15 ÷ 5" (p. 140). Mighton continues by saying that before teaching the long division algorithm he also teaches "students to understand the concept of a remainder" (p. 144).

Students at any grade-level only can understand new mathematical concepts if they have the required knowledge base to build on. "An extensive body of research on arithmetic operations, such as counting, addition, and subtraction, has shown that success in arithmetic appears to depend on the acquisition of an increasingly organized body of conceptual knowledge" (Bruning, Schraw, Norby, & Ronning, 2004, p. 337). As well "an examination of how students solve algebra word problems suggests that difficulties stem from students' failures to learn flexible and powerful strategies based on conceptual knowledge" (Bruning et al, 2004, p. 337). It cannot be overstated that developing students' conceptual understanding of mathematics is what is necessary for further extension of mathematical knowledge.

Procedural Fluency

Procedures and Concepts

As well as conceptual understanding, mathematical learning involves learning certain procedures known by mathematicians as algorithms. Mathematical procedures or algorithms are precisely outlined rules that tell learners how to get a certain output when given a certain input and a finite number of steps (National Research Council, 2001). For example, adding, subtracting, multiplying, and dividing numbers can be done using pencil and paper procedures, mental computations, finger counting, an abacus, or a calculator. For each method people have devised various algorithms to aid them with their calculations. But as Van de Walle and Folk (2008) state, "All mathematical procedures can and should be connected to the conceptual ideas that explain why they work" (p. 28).

John Mighton (2003) maintains that any student can learn to do mathematics if it is presented in small enough steps. He believes that presenting a lesson should be done in small manageable pieces and not by showing the students all the steps at the same time. He states that teachers need to let students practice each small step so that they learn it well before they go on to the next step. For example, when learning fractions, "students learn to recognize patterns, select appropriate algorithms, and carry out complex sequences of operations. The goal of even the most mechanical exercise in the unit is to prepare children for more advanced conceptual mathematics" (pp. 63-64). When adding two fractions with the same denominator, Mighton suggests teaching the rule by first giving pictorial representations of fractions such as 1/4 + 2/4 = 3/4. After doing a few examples and getting them right, students need to be asked to add three fractions with the same denominator. Teachers need to let the students figure out the rule, then reinforce it with a few examples. Next, teach students to subtract two fractions with like denominators (the same denominators) and finally let them solve mixed addition and subtraction of fractions with like denominators, such as 3/5 + 1/5 – 2/5 = ?, before going on to fractions with different denominators. Each step needs to be learned well before going on to the next step. Further, Mighton states that "students should never be expected, when learning a new operation, to employ knowledge or a skill that they haven't mastered" (p.31). He goes on to say that "[i]t would be unwise, for instance, to teach a student who has a shaky grasp of the six-times table to add fractions by producing examples with denominators divisible by six" (p. 31).

Wright, Martland, Stafford and Stanger (2002) have a similar perspective. They stated that it is important for primary teachers "to learn as much as possible about the child's current knowledge in early number and to do this it is necessary to observe closely, children's words and actions in appropriate mathematical contexts" (p.8). Children learn mathematical procedures and concepts best when the new material is built on their current knowledge.

Teaching Strategies

In their book *Teaching Number: Advancing Children's Skills and Strategies,* Wright, Martland, Stafford, and Stanger (2002) describe their strategies for teaching children in primary grades to count, add, subtract, multiply and divide in detail. The success of their method is the highly individualized or one-on one teaching described in the first two chapters. Whole class teaching strategies described in the book, such as counting by 2s, 10s, 5s, 3s and 4s, which set the stage for multiplication and division, are also suggested by other researchers (Baron, 2004b, 2004c; Mighton, 2007; Van de Walle and Folk, 2008).

Other strategies that teachers can use to help students be at ease with numbers are for example: (a) manipulating numbers, and (b) using appropriate procedures with ease. Counting up or down is a process for teaching addition and subtraction facts, a method that many teachers and researchers (such as: Baron, 2004a, 2004d; National Research Council, 2001; Van de Walle & Folk 2008; Wright, Martland, Stafford, &Stanger, 2002) support.

Another procedure is the "Ten-Frame Facts" model presented by Van de Walle and Folk (2008). These are arrays of 2 rows and five columns (a 2-row by 5 column paper model) with a specific number of dots (10 or less) on each paper model. It is valuable for seeing certain number relations. "The ten-frame helps children learn the combinations that make 10. Ten–frames immediately model all of the facts (from 5 + 1 to 5 + 5) and the respective turnarounds. Even 5 + 6, 5 + 7 and 5 + 8 are quickly seen as two fives and some more, when depicted with these powerful models" (p. 175). For example when adding 5 + 8, the students might think of that as 5 + 5 + 3.

Baron (2004a) also teaches addition facts by using ten frames as well as by using models such as: cube trains consisting of one row of cubes, and dominoes. The importance of the part-part-whole relationship and the commutative, or "turnaround" property of addition is stressed as a way of conceptualizing a number. Baron teaches subtraction facts by using ten frames, dot patterns and number lines. She uses a variety of different strategies in order to ensure that each of her students can choose a method that works best for him or her.

Pattern Building

Hindy (2003), on the other hand, teaches oral and mental computation in order to lead her students to computational fluency. She defines computational fluency as "having a sense of numbers and their relationships, looking at the whole mathematics problem, manipulating numbers by breaking them apart and putting them together, and doing mathematics mentally" (p.46). Hindy states that she strives to make mathematics important, meaningful and fun for her Grade five students. She teaches computational fluency by using what she calls "ArithmeTricks", strategies described in a book written by Edward H. Julius (1995). There is a summary of twelve "ArithmeTricks" that she placed in a table. The first one is a pattern building technique combined with problem solving. Her questions are stated orally and the pattern is written on the whiteboard or overhead projector. Here is a similar example:

$$5 \times 3 = 15$$

$$5 \times 30 = 150$$

$$5 \times 300 = 1500$$

$$5 \times 3000 = 15000$$

Hindy calls this the "zeros" trick because you can cover up the zeros. Another "trick" she used was to add 10 and subtract 1 whenever you wanted or needed to add 9. For example:

$58 + 9 \rightarrow 58 + 10 = 68, \quad 68 - 1 = 67.$

These pattern building techniques helped Hindy's students discover short cuts to solving arithmetic problems. (Hindy, 2003)

Wicket, Kharas and Burns (2002) use similar ideas. They teach fluency through their carefully designed lesson plans for "Algebraic Thinking". Each lesson develops a specific concept. Pattern development is a prominent factor in their lessons. They draw a T-chart on the board labeling the two sides of the function. For example, their first lesson was a funny doubling game. According to their funny story, every time something was dropped into the pot, two of that thing would be pulled out. So, the T-chart was divided into two parts, "in" and "out". The teacher would place numbers (only counting numbers) under the "in" and the students had to decide or calculate what numbers would go under the "out". Later, for each set of ordered pairs on the T-chart, the teacher, with the aid of the students, would write an equation.

Connections

Bruning, Schraw, Norby, and Ronning (2004) emphasize that a large body of research has shown that success in arithmetic seems to depend on an extensive body of conceptual knowledge and that procedural knowledge needs to be closely linked with conceptual knowledge.

Most estimation and computation skills depend on using number relationships while some depend on numerical patterns (Menon, 2003). Menon claimed that short cuts motivate students, especially those with little success in computational mathematics. He used frequent activities to aid his students with pattern learning, which, he noted, is recommended by NCTM. Menon further stated that these activities prompted students to learn to perform rapid mental calculations, and he gave examples such as multiplying and dividing by 5, multiplying and dividing by 49, and multiplying by 15. Menon maintained that these shortcuts can be taught in such a way that number sense and conceptual understanding are enhanced.

"Connections are most useful when they link related concepts and methods in appropriate ways" (NRC, 2001, p. 119). When teachers create a rich mathematical environment in their classrooms through thoughtful planning and teaching, they create room for the development of children's mathematical knowledge and strategies (Murphy, 1991; Wright, Martland, Stafford & Stanger, 2002). It is likely that formal or invented algorithms, although powerful tools for solving problems, are only remembered if they are based on an understanding of relevant mathematical concepts. Rubenstein (1985), for example, described sample activities that go beyond the elementary school years. They included: number sense, beginning algebra, and pre-calculus. She claimed that by making mental math a high priority in her classes, her students became more flexible thinkers, were more able to use multiple approaches to problem solving, and had an easier time learning topics which required numerical and symbolic fluency.

In order to analyze what type of problem solving procedures children use in different situations, Carraher, Carraher, and Schliemann (1987) randomly selected and tested 16 third graders from two public schools in Brazil. The ages of the students varied from 8 to 13 years. Each student solved a total of 30 arithmetic problems that were presented to them orally. The "experimenter" had selected items from three situations: a simulated store situation, an embedded word problem, and computation exercises. The researchers noted that the type of calculation used by the students to solve each problem depended on the meaningfulness of the situation presented to the children in each specific problem. "Situations that present quantities embedded in meaningful transaction - such as calculating the amount of change after a purchase or the number of children in a school - seem to engage children in problem-solving procedures of the manipulation-of-quantities type" (p. 95). Interestingly, in this study real-life problems were solved by the students orally, while classroom type computation problems were solved using written algorithms. Carraher and colleagues concluded "that oral mathematics can no longer be treated as merely as idiosyncratic procedures nor inconsequential curiosities. It involves sophisticated heuristics that are general, revealing a substantial amount of knowledge about the decimal system and skill in arithmetic problem solving" (Carraher, Carraher, & Schliemann, 1987, p. 96).

Auditory Memory

Importance of Memory

The National Research Council (2001) states that students should have certain facts and procedures committed to memory so they do not need the aid of their teachers, friends or mathematical rulebooks and tables to perform simple calculations. "Automated processes in attention, perception, memory, and problem solving allow us to perform complex cognitive tasks smoothly, quickly, and without undue attention to details" (Bruning, Schraw, Norby, & Ronning, 2004, p. 7).

Expert musicians are known, and at times envied, for their amazing memories. What makes them so good at memorizing? Chaffin and Imreh, (2002) observed a concert pianist when she was studying a new piece for a performance and noted: "Like other expert memorists in other domains, she engaged in extended retrieval practice, going to great lengths to ensure that retrieval was as rapid and automatic from conceptual (declarative) memory as from motor and auditory memory" (p. 342). Chaffin and Imreh continue by quoting Ericsson & Kintsch (1995): "The feats of expert memorists have been explained in terms of three principles: meaningful encoding of novel material, use of a well-learned retrieval structure, and rapid retrieval from long-term memory" (Ericsson & Kintsch as quoted in Chaffin & Imreh, 2002, p. 342).

Memory Theories

According to Bruning and colleagues (2004, p. 15), memory researchers have traditionally divided memory processes into three stages: acquisition, storage, and retrieval. They suggest, however, that "[a]lthough it is convenient occasionally to distinguish among encoding, storage, and retrieval, it is even more important to remember that all memory functions are integrated" (Bruning et al., 2004, p. 96).

According to the *APA Dictionary of Psychology* (VandenBos, 2007), auditory memory is the type of memory that retains information obtained by hearing. Auditory memory may be either short-term or long-term, and the material retained may be either linguistic (e.g. words) or nonlinguistic (e.g. music). Further, the *APA Dictionary of Psychology* defines auditory memory span as the number of simple items, such as words or numbers, that can be repeated in the same order by a person after hearing the series once, and states that the auditory memory span indicates the capacity of a person's working memory.

Educators and psychologists give importance to auditory memory, as it is one of the items tested on academic screening tests. For example, word recognition and auditory memory were significant variables in predicting mean academic grade for grade one students when using The Einstein Assessment of School-Related Skills (Bennett, R. E., Gottesman, R.L., Cerullo, F. M., & Rock, D. A., 1991).

Automaticity

Although instant recall is of great value, many students lack the ability of instant recall in many areas. Williamson (2007) suggested that we attempt to improve students' rapid recall by designing mental math activities that make students' learning more active.

Arithmetic basic facts in addition, subtraction, multiplication and division need to be so well remembered that their retrieval becomes automatic. Yet Cumming and Elkins

(1999) in their study of 109 students ranging from Grade 3 to Grade 6 have noticed that there was a "lack of development of thinking strategies and automaticity by many of the children at even high grade levels" (p. 174). The authors concluded that when students do not show an ability to reply to simple addition automatically, they "may be disadvantaged in other areas by this lack (p.175). Other research by Bruning and collegues (Bruning, Schraw, Norby, & Ronning, 2004) showed that the development of automaticity is slow at the start, but that the knowledge of facts eventually becomes so automatic that students are able to not only retrieve but also use the facts correctly. Performance continues to improve with practice even after an extended amount of practice. "Sensory memory briefly processes a limited amount of incoming stimuli. Visual registers hold about seven to nine pieces of information for about 0.5 second. Auditory registers hold about five to seven pieces of information for up to four seconds" (Bruning et al., 2004, p. 26). The authors noticed that skilled learners used a variety of information processing strategies known as encoding processes to move new information from short-term to long-term memory and use a variety of retrieval processes to access information in long-term memory for use in short term-memory. They write, "How we encode to-be-remembered information makes a huge difference in how well we remember it. One very important dimension of encoding is rehearsal" (Bruning et al., 2004, p. 66). Students wishing to commit information to long-term memory need to access a schema that activates prior knowledge that is relevant to the new information, and subsequently connects the new and stored information to each other. Practicing with peers, using oral rehearsal promotes such learning. Rehearsal is needed in order for students to make math strategies and facts automatic and more easily transferable.

Mental Mathematics

Importance of Mental Mathematics

Hope has explained the importance of mental mathematics as follows: "Mental mathematics is the cornerstone for estimation and leads to better understanding of number concepts and number operation" (Hope, 1990, as stated in The Western Canadian Protocol, 1996, p. 8). Mental mathematics is the ability to perform mathematical calculations without the aid of a calculator, abacus, pencil and paper, or manipulative objects. The ability to perform simple mental calculations is useful not just for students but also for people in all walks of life, "for workers, consumers, and citizens" (Rubenstein, 2001 p.442). Having the ability to calculate and solve problems mentally is an important lifelong skill (Manitoba Education and Training, 1997). Mental mathematics was used for many centuries, both in and out of school, long before the invention of paper, pencils or calculators. In Japan, for example, the use of mental computation in everyday life dates back to the 10th century (Reys, Reys, Nohda, Ishida, Yoshikawa & Shimizu, 1991).

Articles written by classroom teachers, including Burns (2007), Menon (2003) and Rubenstein (2001), described mental math activities that they had their students do orally during math class. Calculating answers in our head is an important skill, and Burns (2007) has suggested that teachers give this skill a "starring role" in their mathematics teaching. She helps develop her students' mental math skills through an activity she calls "hands on the table math". She encourages students to share their ideas and hear from their classmates, in order to “broaden their repertoire for computing, which helps support their number sense and builds flexibility” (p. 52).

Schools may need to place more emphasis on mental mathematics. Studies such as the one by Reys, Reys, Nohda and Emori (1995) show that students find mental computation more challenging than written computation, that most students prefer the pencil-and-paper, right to left calculation method, and do not attempt to try any other method of calculation even on the most obvious sums. In addition, most children and young adults cannot perform even the simplest mental calculations nor are they aware that a mental calculation is often the most convenient method of solution (Hope, Rays, & Rays, 1988).

Skilled and Unskilled Students

Mental mathematics skills can be developed. In a case study of a 13 year old highly skilled mental calculator, Hope (1987) stated that out of the 50 multiplication items that were presented orally, the girl calculated correctly and rapidly 46 items in a single attempt, averaging 1.75 seconds per calculation. One exception, which took her 50 seconds, was the calculation of 123×456. She also stated the corrected response to the four incorrect items. Her mental calculation techniques included distributing of one or more factors and factoring strategies (for example, the above question 123×456 can be looked at as $(100 \times 456) + (20 \times 456) + (3 \times 456)$. She had a remarkable ability to recognize prime numbers and an incredible memory for squares, recalling within a second most of the squares of two-digit numbers. Recognizing number patterns was another of her abilities.

Hope noted that a high level of proficiency in mental calculation seems to require an interest in number patterns and properties and, as in other everyday cognitive tasks, success in mental calculation depends on the ability to select the correct method for each task.

Hope and Sherrill (1987) have argued that skilled and unskilled students do not use the same types of calculation strategies. In their effort to determine the characteristics of unskilled and skilled mental calculators, Hope and Sherrill administered, on an individual basis, a 30 item mental multiplication test to 15 skilled and 15 unskilled Grade 11 and 12 mathematics students who were chosen based on their performance on a previous mental multiplication test attended by 284 students. The study showed that the unskilled students were so used to pencil-paper calculations that many heavily relied on such calculations rather than making use of simple mental calculations. In fact, most of the unskilled students calculated as if they had an imaginary writing pad. The skilled students used a variety of strategies during their calculations with the most frequent being the distribution strategy. The tendency of skilled students to calculate from left to right, thus calculating the significant digits first while doing mental calculations, was also observed by Hope and Sherrill (1987). "Because most written computational algorithms seem to require a different type of reasoning than mental algorithms", Hope (1987) has argued that "an early emphasis on written algorithms may discourage the development of the ability to calculate mentally" (p. 341).

Classroom Activities

Irvine and Walker (1996) have suggested that teachers make quick mental math exercises part of the daily routine at the beginning and end of the day, as students line up or between other activities. Mental math activities should not stop with whole numbers but should continue with fractions, decimals and percentages and other basics added to the list each year.

Rubenstein (2001) has been developing strategies for implementing short mental activities in all of her classes, and has described the following benefits: "When students have regular opportunities to estimate, share orally, evaluate, compare their approaches, and transfer strategies to new settings, they feel challenged and ultimately empowered" (p. 443). She also stated that students took pride in being able to use these new skills and in not needing to rely on their calculators.

McIntosh (1998) has suggested that we should shift our emphasis in teaching mathematics to the teaching of mental computations. He reasons that formal algorithms "do not correspond to the ways in which people tend to think about numbers" (p.44) but restrict children's thinking. He has stated that mental computation strategies "are flexible and can be adapted to suit the numbers concerned" (p. 44). In addition, he has claimed that students will develop number sense by analyzing the numbers involved and deciding on the strategy to be used.

Benefits of Mental Mathematics

Good estimation skills are a highly skilled mental math activity. Reys, Bestgen, Rybolt, and Wyatt (1982) designed a study to explore and determine what thinking strategies students and adults use, and Dowker (1992) designed a study to determine what thinking strategy professional mathematicians use when asked to estimate the answers orally (i.e., without pencil and paper and think aloud while estimating). These studies revealed that the subjects used a variety of strategies for their mental calculations during the interviews. The results indicated that the subjects were flexible in their thinking, used a great number and variety of estimation strategies, which involved the understanding of arithmetic properties and relationships, and were quick in choosing the approach to a particular problem that seemed to be comfortable and natural to them. They were able to change numerical data to a mentally manageable form, understood place value, had a quick and accurate recall of basic facts, knew and were able to use number properties and, in general, had good number skills, cognitive processes, and affective attributes.

In their above mentioned research study, Reys et al. suggested that mental mathematics aids students to think and calculate efficiently and accurately. "Students should possess adequate mental arithmetic skills so that they are not dependent on calculators to do simple computations and are able to detect unreasonable answers when using calculators to solve harder computations" (NCTM, 1989, p. 96). As Menon (2003) stated, "Focusing on instruction, then, on the use of number relationships for mental estimation and calculation seems pedagogically sound and should bring about great success in, and understanding of, computation" (p. 479).

The National Research Council (2001) has stated that being able to think mathematically is very important today. "Citizens who cannot reason mathematically are cut off from whole realms of human endeavor." (p. 16). They have further stated that innumeracy deprives people of opportunities as well as competency in daily tasks.

Students today need to be given the opportunity to become literate in mathematics (basic arithmetic, algebra, geometry, or pre-calculus) as well as in reading if they are to be eligible for higher education. Improving students' mathematical performance in and out of school is of major importance.

We are living in a highly technological world. Technological jobs are based on mathematical knowledge. Students, therefore, need to learn mathematics in order to be able to access many jobs in the labour market (National Council of Teachers of Mathematics, 2000; National Research Council, 2001). As well, "people will be called on more and more to evaluate the relevance and validity of calculations done by calculators and more sophisticated machines" (NRC, 2001, p.16). Furthermore, the National Research Council (2001) states that students need to be able to connect school mathematics to everyday life mathematics. Mathematically literate students know mathematics (understand the concepts), are able to do mathematics (know when and how to use certain procedures), and work efficiently and correctly.

Mental Mathematics Across the Grades

Van de Walle and Folk (2008) believe that teachers can extend their students' knowledge of early number relationships to working with larger numbers. For example, they contend that students should be able to do mental mathematics in any grade. The use of mental math activities should not be restricted to the primary and elementary classroom as high school students also have a need for mental computation. For instance, Lewkowicz (2003) uses mental computation games to introduce beginning algebra to her students.

As previously mentioned, Rubenstein's (2001) sample activities go beyond the elementary school years. They include number sense, beginning algebra, and pre-calculus. This is a good example of knowledge extension from simple to more difficult mathematical concepts. She states that by making mental math a high priority in her classes, her students become more flexible thinkers, are more able to use multiple approaches to problem solving, and have an easier time learning topics which require numerical and symbolic fluency.

The literature discussed in this chapter is presented to the reader to provide a context for the research question: Can Oral Mathematics drill activities involving the understanding of mathematics concepts (and not just basic facts) be designed and implemented in a way that increases accuracy and speed to the point of developing automaticity? The literature discussed in this chapter examined: conceptual understanding, procedural fluency, auditory memory, mental mathematics, and knowledge transfer; these are the relevant issues surrounding Oral Mathematics. The National Research Council (2001) has emphasized the ever growing importance of mathematics and of mathematics learning. Hope (1990) and the *Western Canadian Protocol* (1996) have called attention to the importance of mental mathematics in mathematics learning, while Bruning et al. (2004) have discussed the importance of auditory memory for the learning of mathematics. Instant recall or automaticity was an integral part of the auditory memory section. The literature supports the view of the importance of understanding of concepts for the purpose of learning new concepts (NRC, 2001; Mighton, 2007), new procedures (Mighton, 2003), and of transferring knowledge to new situations (Boaler, 1997). The literature strongly suggests that when teaching students mathematics, teachers need to make sure that students understand the concept upon which a lesson is focused (NRC, 2001), that the material is presented in small steps (Mighton, 2003), and that rehearsal, for the purpose of retention of the new material, is incorporated (Baron, 2004a; Mighton, 2003; and Van deWalle & Folk, 2008). Conceptual understanding and mental mathematics need to go hand in hand in order to help students in mathematics learning (WCP, 1996). As the literature review demonstrates, mental mathematics skills can be developed (Hope, 1986), teachers should place more emphasis on teaching mental mathematics (McIntosh, 1990), and teachers need to have the students do mental math activities orally (Burns, 2007; Mennon, 2003 and Rubenstein,2001) during math class. The importance of mental mathematics, as described above, leads to the importance of my Oral Mathematics drill activities as described in Chapter 1. Rehearsal of basic arithmetic facts and certain mathematical procedures to the point of automaticity may take time, as stated earlier, and require diligence on the part of the students, but success can be achieved when rehearsal is built on prior conceptual knowledge as was stated above with reference to the literature.

The next chapter will focus on the description of the method used in my study. It includes the description of the data gathering method, and the description of the design and delivery of the Oral Mathematics drill activities. The results and discussion of the quantitative data will be presented in Chapter 4 and the results and discussion of the qualitative data will be presented in Chapter 5.

CHAPTER 3:

METHOD

Research Design

Mixed Method Design

Data collected for this study is qualitative as well as quantitative in nature. Therefore, the approach used is a mixed-method research design referred to as the triangulation mixed-method (McMillan, 2004). McMillan (2004) explains that in the triangulation mixed-method research design both data collections (quantitative and qualitative) are used at about the same time, each strengthening the weakness of the other method and, thereby, giving greater credibility to the findings.

Participants

The participants in this study were five Grade 9 (Senior I) students from a secondary school (Grades 9-12, Senior I-IV) located in a larger city in Western Canada. The participants were three male and two female students. All five participants were above average achievers, who were participating in a variety of after-school activities. Since all participants were volunteers, a cross-section from all three achievement levels (below-average, average, and above-average) was not possible to obtain. The five participants stated that they liked mathematics and were interested in becoming even better learners of mathematics. Eight students volunteered for the study, but due to after-school activities, three had to miss too many sessions and decided to drop out of the study. For research validity and ethical reasons, the data collected from these three students is not included in the study.

Data Collection Tools

Various data collection tools were used for this study. First, researcher designed quizzes (see Appendix A, pp. 121-172), which were based on the Oral Mathematics drill activities (see Appendix B, pp. 173-186), were used to collect daily responses to questions, and the time each participating student spent on each quiz was recorded. Second, researcher designed tests (see Appendix C, pp. 187-192) were used to record data to show mathematical knowledge on a cross-section of mathematics topics and the time it took each participating student to respond to each question. Third, researcher designed survey questionnaires (see Appendix D, pp. 193-194) were used to illuminate students' view of the effectiveness of the Oral Mathematics drill activities. Fourth, researcher's written observations during the daily Oral Mathematics drill activities were used to keep track of either unusual or frequently occurring significant student replies, student behavior or student comments. Fifth, an audio-tape-recorder was used to record the Oral Mathematics test sessions with each student participant in order to later analyze each reply by each individual student for correctness and time spent replying.

Data Collection Process

The school board and the school principal were both provided with an information letter and a consent form (see Appendix E, pp. 195-197 and pp. 197-201). Having attained the written consent of the board and principal, the school secretary was asked to distribute to each Grade 9 (Senior I) student a set of four documents: (a) an information letter to the parent/guardian (see Appendix E pp. 201-202), (b) an information letter to the student (see Appendix E pp. 204-205), (c) a consent form to the parent/guardian (see Appendix E pp. 202-204), and (d) an assent form to the student (see Appendix E pp. 206-208). The school secretary was asked to also collect the incoming signed forms, to notify the students of the time and place of the initial meeting with the researcher, and to keep the names of participating students anonymous.

During the initial meeting with participating students, the details of the research study as outlined on the information sheets were reviewed, times for the pre-intervention tests were scheduled, and the pre-intervention questionnaires were completed by the student participants. Next, audio-tape-recorded pre-intervention tests were conducted with each student individually. This was followed by four and a half weeks of daily intervention, after which a second round of audio-tape-recorded tests (mid-intervention) were individually conducted with each student. Following the mid-invention tests, daily interventions over a period of five more weeks were conducted. A third round of audio-tape-recorded tests (post-intervention) was conducted after completing the five weeks of interventions. The study ended with a final meeting during which post-intervention questionnaires were completed by the student participants. At the end of the final meeting the students were thanked for their participation in the study. To view the timeline showing dates and activities from start to finish, see Appendix F, p. 209.

Each daily session during the intervention period consisted of two parts. During the first part (at the beginning of the session) each participant completed a written quiz (composed of 10 questions) and returned it right after completion. The time that was spent on completing the quiz was marked on the paper as it was handed in for correction and data collection. This quiz writing took 5 to 10 minutes. During the second and main part of the session, Oral Mathematics drill activities were conducted. Questions were asked orally and were also displayed on the overhead projector, one set of questions at a time. Detailed description of the nature of the questions and the number of questions in a set will be provided later in this chapter. (see Appendix B, pp. 173-186, for sample questions). This second part, during which the students orally responded to the questions as a class, took 5 to 20 minutes. If the reply was correct, the next question was asked orally; and the process continued until all ten questions on the activity sheet had been asked or until an incorrect reply was given by the group or an individual student. When an incorrect reply was given by the group or an individual student, the process was interrupted with an explanation of the concept and an invitation for questions seeking clarification. This process will be further explained later in this chapter.

Data Analysis Process

Quizzes. The quizzes were used to determine the accuracy and speed with which the student participants responded to the orally presented ten questions, which related to the corresponding set of questions in the Oral Mathematics drill activities. Since each set of Oral Mathematics drill activities consisted of specific types of questions relevant to particular mathematical concepts, the quizzes were also used to help determine what types of questions lend themselves better to automatization and what types do not. Data collected from the quizzes were analyzed, and sample data tables and graphs accompanied the analysis.

Tests. Each participant's taking of the pre-, mid-, and post-intervention tests was audio taped and transcribed by the researcher. The transcribed data (see Appendix G, pp. 210-226) was analyzed for accuracy of response and for speed, as well as difficulty of question (conceptual and retentive). Data collected from the tests were analyzed based on the following coding: numerical, pictorial, and word problems. The level of difficulty was increased with each subsequent test (pre-intervention, to mid-intervention, to post-intervention). This means that although, each of the three tests consisted of 22 questions, the number of questions belonging to the: (a) numerical, and (b) word problems were not the same throughout the three tests. On each test there were always four pictorial types of questions. The questions on the pre-intervention test consisted of 12 numerical, 4 pictorial, and 6 word problem types. The questions on the mid-intervention test consisted of 10 numerical, 4 pictorial, and 8 word problem types. The questions on the post-intervention test consisted of 6 numerical, 4 pictorial, and 12 word problem types. (See Appendix G, pp. 210-226, to view the transcripts and coding on the three complete tests.)

Surveys. The survey questions were designed to collect data on each student's perception of the effectiveness of Oral Mathematics drill activities and on their capabilities and habits relative to mathematics learning. Data collected from the surveys were coded as school-based assignment (such as questions # 6 - 8 on the initial survey), school-based test/quiz (such as questions # 14 and # 15 on the initial survey), and Oral Mathematics drill activities (such as questions # 16 on the initial survey). To view survey data and coding details, see Appendix I, pp. 231-238.

Researcher's Observations. Data collected during observations were all for the purpose of supplementing and enhancing the interpretation of the quantitative data. Of special interest were student comments or questions during the Oral Mathematics drill activities, and the use of pen and paper, fingers, and quick, barely audible counting strategies during tests.

Oral Mathematics Drill and Assessment Activities

Activities

Designing activities which involved conceptual understanding was a crucial part of this study. In order to design the Oral Mathematics drill activities I took the following steps:

1. I reviewed the K-8 Manitoba Mathematics Curriculum Guide to view concept development across the grades in all four strands: (1) Number Strand, (2) Patterns and Relations Strand, (3) Shape and Space Strand, and (4) Statistics and Probability Strand.
2. Considering one strand at a time, I designed a sample question for each concept covered in the respective strand of the Grade 8 section of the K-8 Mathematics Curriculum Guide of Manitoba. My objective was not to present new material but to develop automaticity of material taught in prior grades.
3. After consideration of all sample questions, I eliminated those questions which were based on concepts that require short-term retention of multiple partial solutions, for

example calculating the surface area of a 3-D object other than a cube. My reasoning for eliminating these types of questions was that there would be too many numbers involved that needed to be kept in mind while still having to do more calculations. For example, calculating the surface area of a rectangular box with a base area of 8cm by 5cm and a height of 7cm would mean that students would have to (a) calculate the area of the base of the box ($8\text{cm} \times 5\text{cm} = 40\text{cm}^2$) and (b) double it since there are two equal areas ($40\text{cm}^2 \times 2 = 80\text{cm}^2$), (c) keep this quantity in their working memory while (d) calculating the next area ($5\text{cm} \times 7\text{cm} = 35\text{cm}^2$) and (e) doubling it ($35\text{cm}^2 \times 2 = 70\text{cm}^2$), (f) add this quantity to the previous quantity ($80\text{cm}^2 + 70\text{cm}^2 = 150\text{cm}^2$), (g) keep this sum in their working memory while (h) calculating the third surface area ($7\text{cm} \times 8\text{cm} = 56\text{cm}^2$) and (i) doubling it ($56\text{cm}^2 \times 2 = 112\text{cm}^2$) and (j) adding this result to the previous calculation to get the final answer ($150\text{cm}^2 + 112\text{cm}^2 = 262\text{cm}^2$). In my mind, these types of questions do not lend themselves well to mental calculations. I am not suggesting that they cannot be calculated mentally, I am simply suggesting that these types of questions take longer to calculate and, thus, do not lend themselves well to drills for the purpose of achieving automaticity.

4. Again, working on one strand at a time, I expanded each sample question into a pattern (series of questions), thus forming sample drill activities (see Figure 3-1).
5. I used 10 of the designed sample drill activities from the Number Strand (see Appendix B, p. 173) as my first set of Oral Mathematics drill activities and presented them to the student participants.

6. I designed similar drill activities by varying the difficulty level, based on the students' responses to the first set of drill activities (see Appendix B, pp. 173-174 to compare the difficulty level of the questions in drill activity #1 and drill activity #2). The design of the activities from all four strands followed the described process (see Figure 3-1 for sample activities or Appendix B for all the drill activities).

Figure 3-1 Examples of Oral Drill Activities: One Example from Each Strand

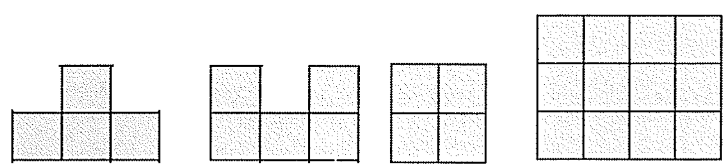
(1) What is 5 % of:

30, 50, 70, 80, 100, 120, 150, 200, 450, 900?

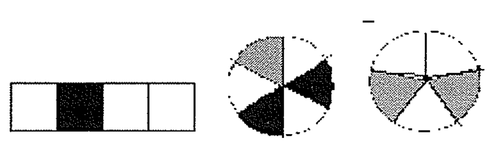
(2) What is one more than the double of each of the following:

3, 5, 7, 9, 11, 13, 15?

(3) State the perimeter of the following shapes:



(4) Express the shaded area as a fraction.



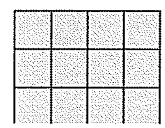
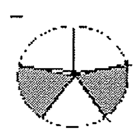
Assessment Process Using Daily Quizzes

In order for the data gathering for the quizzes to be based on the Oral Mathematics skills, certain rules and processes needed to be put in place. The required rules and processes were as follows:

1. The student participants of this study were instructed not to bring a calculator or paper when they came for the Oral Mathematics drill activity sessions. They were only to bring a pen or pencil with them for the purpose of completing a quiz.
2. Each quiz was administered prior to the drill activity portion of the Oral Mathematics session and consisted of questions covering one example from each activity (see Appendix A, pp. 121-172, for the quizzes.).
3. Each quiz was collected immediately after completion, and the time that it took a student to complete the quiz was recorded.
4. The quiz was not corrected during the session.
5. Student participants were not told how many questions (or which questions) they answered correctly. The only support for understanding the quiz problems was provided through the Oral Drill Activities, which involved similar problems as those on the quizzes.
6. Quiz questions were not stated orally but were written down on a quiz paper requiring students to read each question on their own as well as writing down the reply independently.

To view sample quiz questions see Figure 3-2 or Appendix A. Had the quiz been written immediately following the Oral Mathematics drill activities the results might have been different. However, writing the quiz immediately before the start of the drill activities meant that each quiz was written at least 24 hours after exposure to the drill activity, and therefore was more likely evidence of learning stored in long term memory.

Figure 3-2 Sample Quiz Questions Based on the Oral Mathematics Drill Activities from Figure 3-1.

1. What is 5% of: 80 .
2. What is one more than the double of the following: 7 ?
3. State the perimeter of the following shape: 
4. Express the shaded area as a fraction. 

Drill Process

In order to insure that students would practice Oral Mathematics skills rather than reliance on some other means of calculation such as using paper and pencil or a calculator, the students were instructed not to use the pencil or pen they had brought for the quizzes during the drill sessions. In addition, the students had no access to the drill activities other than during the Oral Mathematics drill activity session. Following is a description of a single drill activity session and a block of drill sessions.

Description of One Oral Mathematics Drill Activity Session

1. Each Oral Mathematics drill activity session began with each participant completing a written quiz and returning it to me immediately after completion; I then recorded the time spent completing it.

2. Then the Oral Mathematics drill activities began. Each drill activity consisted of one set of multiple interrelated questions put into a one-question pattern form (see figure 3-1 for examples). I read the question of the first activity out loud and also displayed it on the overhead projector.
3. All students replied orally at the same time.
4. If the reply was correct, I continued with the next question in that same activity (i.e., What is 5% of 50?) until the activity (pattern) was complete. To view sample drill activities from the three other strands, see Figure 3-1 or Appendix B, pp. 173-186.
5. Next I read the questions of the second activity out loud and also displayed each of them on the overhead projector. The process continued until all the questions in all ten activities on the activity sheet had been asked (see Appendix B, pp. 173-186 for the activity sets) or until an incorrect reply was given by the group or an individual student.
6. When an incorrect reply was given by the group or an individual student, I stopped the drill activity. Then I said: "It is O.K. not to understand. Let's see, what makes this question difficult?" If none of the students would ask a question, I tried to clarify the concept and then asked the group to redo that particular drill activity. I always tried to explain the concept and never provided only a procedure to follow. If a student stated a specific concern or asked a question, I spoke to that concern or question until the student said "It's O.K. I get it." If it looked like the student needed a longer explanation, which seldom happened, we came to a common agreement to clarify the problem immediately after the Oral Mathematics drill session, thereby not holding

back the rest of the group. The actual drill activity portion of the Oral Mathematics drill activity session required between 5 to 20 minutes.

One set of Oral Mathematics drill activities was presented to the student participants for more than one day. For the purpose of this study, the number of days in which one specific activity set was presented constitutes one block, which is described next.

Description of One Block of Oral Mathematics Drill Activity Sessions

Day 1

- The students' first exposure to a new set of activities was always a quiz; therefore the first quiz based on a certain set of activities was always a pre-activity quiz.
- After all the students completed and handed in the pre-activity quiz, I asked them if they found it easy or difficult. Then the drill session was conducted as previously described.

Subsequent days

- The quiz that I gave the students on the second day was identical in content to the first quiz but the order of the questions had been changed.
- The first day's activities were repeated. With certain activities by this day the activity patterns were established, meaning that the students understood the pattern and were able to do the activities without explanation and quite fluently.
- At the start of each new day the students wrote a quiz identical in content to the first quiz but with a re-ordering of the questions, so that it was not identical to the order of any previous quiz based on the same activity set.

The last day for an activity set was determined by a combination of factors:

- Were the students able to go through each of the ten activities providing automatic responses?
- Did the students answer all 10 questions accurately?
- If the students were able to go through each of the ten activities with ease providing an automatic response and if the students answered all 10 quiz questions accurately, then that day was considered to be the last day for that particular activity set and the cycle started over with a new activity set.
- If the students were able to go through each of the ten activities with ease but the answers were not all automatic and if the students answered all 10 quiz questions accurately, then I took into consideration their motivational level. If the students sounded excited about the activities, we repeated them again in order to increase the speed; if they gave comments to the contrary, then that day was considered to be the last day for that particular activity set and the cycle started over with a new activity set.
- If the students were not able to go through each of the ten activities with ease and if the students did not answered all 10 quiz questions accurately but made comments expressing disinterest or boredom with the activities, then, for the fear of loosing them to the study, that day was considered to be the last day for that particular activity set, and the next day the cycle started over with a new activity set.

In this chapter, I described the design of the study, in general, and the activities and the methods I used for my data collection, in particular. In Chapter 4, I present the results and discussion of the quantitative data, and in Chapter 5 I present the findings from and the discussion of the qualitative data that were collected with this study design.

CHAPTER 4:

FINDINGS FROM AND DISCUSSION OF QUANTITATIVE DATA

As stated in Chapter 1, this study examined in detail the research question: Can Oral Mathematics drill activities involving the understanding of mathematics concepts (and not just basic facts) be designed and implemented in a way that increases accuracy and speed to the point of developing automaticity? In this and the next chapter I will present the data that were collected as outlined in the previous chapter and discuss the findings. The organization of these two chapters is based on the design of the method of the study. The present chapter will deal with the quantitative data, and Chapter 5 will deal with the qualitative data. Since the research question addresses the notion of accuracy and speed as two elements required for automaticity, data has been collected during the study to analyze both of these elements. The quantitative data gathered during this study were data collected on student accuracy and speed based on their daily quizzes, as well as strategically placed tests (i.e.; pre-intervention, mid-way-through intervention, and post-intervention). In this chapter I will, first, present and discuss the quantitative data gathered from the daily quizzes. Second, I will present and discuss the quantitative data gathered from the tests. Third, quiz and test results are analyzed and discussed in terms of automaticity and conceptual understanding.

Findings from Daily Quizzes

Quantitative data on accuracy and speed, as earlier stated, were based mainly on the daily quizzes. In this section, I analyze and discuss how the data support the claim for a general improvement in accuracy and speed in student participants' quiz responses, since accuracy and speed are the two elements which are central to this study.

Data were collected each day of the three-month long study. The complete accuracy and speed data collected for each student based on the daily quizzes is shown in Table 4-1. It is pertinent to have both the number of correct replies for each quiz and the time spent completing each quiz together on one information-sheet as portrayed in Table 4-1, because automaticity depends on both accuracy and speed. In Table 4-1, cells without entry indicate that the respective student was absent at the time the quiz was written. Cells along the word "Activity" name the set number for each particular Oral Mathematics drill activity (numbered 1 to 12), and the cells right under this row, indicate the number of each quiz (numbered 1 to 51). Cells marked "Stu #1" to "Stu #5" represent the five student participants respectively. The test scores in the cells next to "Stu #1" to "Stu #5" are each out of 10, and the time is indicated in minutes and seconds. The average group score is recorded under each quiz. The average group time for each quiz is recorded as well. Each Activity Set is separated by a solid black line in order to make it easier to associate the quizzes with the correct Activity set; for example: Quizzes #1 and #2 belong to Activity Set #1; Quizzes #3 and #4 belong to Activity Set #2, and so forth.

Table 4-1 Daily Quiz Complete Data

Activity	Quiz	S	C	O	R	E		T	I	M	E		
Set #	#	Stu #1	Stu #2	Stu #3	Stu #4	Stu #5	Average	Stu #1	Stu #2	Stu #3	Stu #4	Stu #5	Average
# 1	1		5	5	4	8	5.5		3:20	3:05	3:20	2:25	3:02
	2	9	9	10	10	10	9.6	5:35	1:25	1:05	1:20	1:05	2:06
# 2	3		8	7	7	7	7.25		1:05	1:15	1:00	1:00	1:05
	4	8	9	10	8	10	9	1:50	1:05	0:45	0:50	1:05	1:07
# 3	5	7	8	5	8		7	2:25	3:00	5:20	2:55		3:25
	6	9	9	3	9		7.5	1:50	2:15	3:00	0:50		1:58
	7	8	9	10	10	4	8.2	1:00	3:15	1:50	1:10	3:55	2:14
	8	10		10	9	9	9.5	2:00		2:15	1:25	3:40	2:20
# 4	9	8	7	6	9	7	7.4	5:00	5:30	4:45	9:10	8:20	6:33
	10	10	10	10	8	10	9.6	1:10	1:30	1:30	2:30	2:20	1:48
	11	9	9	9	10	10	9.4	2:20	3:05	2:35	2:50	2:50	2:44
# 5	12	3	4	4	4	3	3.6	4:30	6:05	6:25	4:50	5:50	5:32
	13	8	10	9	9	10	9.2	1:15	1:25	2:15	1:10	1:50	1:35
	14	10	10	6	10	10	9.2	1:25	1:10	1:45	1:30	1:40	1:30
# 6	15	8	9	6	8	3	6.8	2:00	2:20	2:55	1:40	2:30	2:17
	16	7	10	6	9		8	2:00	1:30	1:15	1:10		1:28
	17	9	10	8	10	9	9.2	0:50	0:55	1:05	1:50	1:50	1:18
# 7	18	6	8	7	7	5	6.6	1:25	2:00	1:45	2:00	2:30	1:56
	19	10	9	8	7	7	8.2	0:50	1:00	1:15	1:10	1:15	1:06
	20	8	10	10	9	7	8.8	0:30	0:35	0:40	0:50	0:45	0:40
	21	10	10	10	10	8	9.6	0:40	1:05	0:40	1:00	1:00	0:53
	22		10	10	10	8	9.5		0:35	0:30	0:40	0:40	0:36
# 8	23	5	8	8	10	8	7.8	1:05	1:50	1:15	1:45	2:15	1:38
	24	8	8	9	9	7	8.2	1:30	1:00	1:20	1:10	4:05	1:49
	25	10	10	10		9	9.75	1:10	1:30	1:00		1:10	1:12
	26	10	10	9	9	8	9.2	1:05	1:05	1:10	1:00	2:00	1:16
	27	10	10	10	9	8	9.4	0:45	1:15	0:55	0:45	0:55	0:55
#9	28	6		6	8	9	7.25	3:20		5:30	5:00	5:10	4:45
	29	8	6	6	8	9	7.4	1:20	4:20	2:30	3:20	2:25	2:47
	30	8	9	9	7	10	8.6	0:45	1:25	1:25	1:35	1:00	1:14
	31	8	9		8	10	8.75	0:30	1:10		1:05	0:55	0:55
	32	10	10	10	8	10	9.6	0:40	0:40	0:55	1:10	0:35	0:48
	33	10	10	10		10	10	0:30	0:30	0:30		0:40	0:32
# 10	34		9	2			5.5		5:05	4:30			4:47
	35		8	5		6	6.33		3:50	4:30		5:15	4:31
	36	5	9				7	4:50	2:20				3:35
	37	7	10				8.5	1:50	1:30				1:40
	38	6	7	6		7	6.5	1:35	1:40	2:50		4:15	2:35
	39	5	9	8			7.33	1:50	1:50	2:30			2:03
	40	8	10			9	9	2:20	1:40			2:00	2:00
	41	8		8	6	8	7.5	1:20		2:20	3:30	2:10	2:20
#11	42	8	8	7	6	9	7.6	2:00	2:00	2:10	3:50	3:00	2:36
	43	8	9	7	9	8	8.2	0:50	1:00	1:00	1:50	1:50	1:18
	44	9	9	8	9	8	8.6	0:30	1:15	0:40	0:40	1:00	0:49
	45	9	9	9	9	9	9	0:30	0:50	0:40	0:50	0:40	0:42
	46	7	10	9		8	8.5	0:20	0:20	0:30		0:30	0:25
#12	47	5	7	5		5	5.5	2:40	2:30	2:30		3:30	2:47
	48	10	9	9	6	9	8.6	1:50	1:50	2:30	3:50	2:10	2:26
	49	10	9	10	5	9	8.6	0:45	1:15	1:15	1:30	1:00	1:09
	50	10	9	10	5		8.5	0:50	0:55	0:25	1:00		0:47
	51	10	10	10	8	8	9.2	0:45	0:55	0:55	1:15	1:15	1:01

Data on Accuracy

In this research study, as stated earlier, quizzes were the major source of data on accuracy and speed; other sources were the tests, surveys and the researcher's field notes. The quizzes tracked daily changes in the student participants' responses to the questions in each activity. Quizzes were sample questions from the Oral Mathematics drill activities and, thus, were based on concepts from the four strands: Number, Pattern and Relations, Shape and Space, and Statistics and Probability. Quizzes based on Oral Mathematics drill activities #1, #2, and #3 covered concepts from the Number Strand. Quizzes based on Oral Mathematics drill activity #1 were the simplest since they were taken first and, therefore, the simplest Oral Mathematics drill activity presented to the student participants. These first quizzes involved concepts that lent themselves well to memorization and instant retrieval. Examples included squares of counting numbers 1 through 10 and their inverses, perfect squares up to 100. This was followed by estimation of the square root of near perfect squares such as estimating the square root of 24, which is close to the square root of 25, which is 5. Other concepts covered on the quizzes based on drill activities #1, #2, and #3 included percents, decimals, and fractions, starting with problems of less difficulty and then increasing to a higher level of difficulty. For example, calculating 10% of a certain number preceded calculations of 20%, 30%, and 5% of that number, noting that 20% is double of 10%, that 30% is triple of 10%, and that 5% is half of 10% of a certain number. Quizzes based on Oral Mathematics drill activities #4 to #8 covered concepts from the Patterns and Relations Strand. These quizzes and the activities on which they were based covered several pattern concepts. Some examples (see Appendix A, pp. 121-172, for the quizzes, and Appendix B, pp. 173-186, for the activities) were: (a) addition and subtraction in an oval, (b) fractions in a circle, (c) and polynomial addition, subtraction, multiplication, and division. Quizzes based on Oral Mathematics drill activities #9 and #10 covered concepts from the Shape and Space Strand. Questions included here were: (a) calculating the third angle in a triangle when the other two inside angles are known, (b) calculating the circumference and area of a circle, and (c) calculating the perimeter and the area of squares, rectangles, and right triangles. Finally, Quizzes based on Oral Mathematics drill activities #11 and #12 covered concepts from the Statistics and Probability Strand of the Grade-8 curriculum. Concepts covered in this final portion included: (a) percents, (b) fractions, (c) averages, and (d) calculating probability of an event happening. All quiz questions were based on the Oral Mathematics drill activities. See Figure 3-2, p. 51, for sample quiz questions.

Individual quiz scores as seen in Table 4-1, indicate that with three exceptions, which I will discuss later, in each of the 12 Activity Sets all five students scored higher on their last quiz than they did on their first one. The highest score difference was 7 which was achieved by both Students #1 and #5 in Activity Set #5, the second highest score difference was 6 which was achieved by Student #5 in Activity Set #6 and Student #3 in Activity Set #10. The lowest score difference was 0 (both the first and last score being 8 out of 10) which was achieved by Student #3 in Activity Set #8. The three exceptions I mentioned earlier are as follow: (a) in Activity #10 Student #4 had only one quiz score due to absence, and (b) in Activity #10 Students #1 and #5 each scored 1 less on the last quiz than on the first one, which could be interpreted as a mistake due to speed attempts to increase speed (see the time difference for both students for Activity #10).

The group average quiz scores for every quiz as mentioned earlier can also be seen in Table 4-1. In order to simplify the analysis of the comparison of the first and last group average in each strand, a separate table has been constructed, Table 4-2. The data sources for Table 4-2 were the daily quizzes, with the highest score for each quiz being 10. As described above, this table provides information on the average quiz scores received by all five student participants on the first and last quiz in each activity set: the first and second quizzes for Activity Sets 1 and 2; the first and third quizzes for Activity Sets 4, 5, and 6; the first and fourth quizzes for Activity Set 3; the first and fifth quizzes for Activity Sets 7, 8, 11, and 12; the first and sixth quizzes for Activity Set 9; and the first and eighth quizzes for Activity Set 10. Table 4-2 also provides information on the strand that the quizzes from each activity set focused upon. For all twelve Activity Sets, the last group average quiz score exceeded the group average score for the first quiz. Ten of the twelve last quiz scores were between 9 and 10 points out of 10, and showed gains of 0.9 points for Activity Set #11 to 5.6 points for Activity Set #5. The highest last quiz group average score (10.0 points for Activity Set #9) and lowest last quiz group average score (7.5 points for Activity Set # 10) occurred in the Shape and Space Strand.

Table 4-2 Comparison of Group Average First and Last Quiz Scores

Strand	Activity Set Number	First Quiz Score/10 (mean)	Last Quiz Score/10 (mean)
Number	1	5:50	9:60
	2	7:25	9:00
	3	7:00	9:50
Patterns and Relations	4	7:40	9:40
	5	3:60	9:20
	6	6:80	9:20
	7	6:60	9:50
	8	7:80	9:40
Shape and Space	9	7:25	10:00
	10	5:50	7:50
Statistics and Probability	11	7:60	8:50
	12	5:50	9:20

Data on Speed

Speed is the second of the two elements required for automaticity, therefore, data on speed have also been collected and recorded (see Table 4-1). The time spent on completing each of the 51 quizzes by each of the 5 student participants was recorded. The longest time to complete the first quiz was 9 minutes 10 seconds by Student #4 in Activity Session #4. The shortest time to complete the first quiz was 1 minute by Student #5 in Activity Session #2. The longest time to complete the last quiz was 5 minutes 35 seconds by Student #1 in Activity Session #1. The shortest time to complete the last quiz was 20 seconds by Student #1 in Activity Session #11. In each of the 12 Activity Sets, the time spent completing the last quiz is less for each student than the time spent completing the first quiz with one exception for which the time was the same (1minute 5 seconds for both quizzes by Student #2 in Activity Set #2), and two exceptions for which a longer time was spent on the last quiz than on the first one (in Activity Set #2 Student #5 spent 5 seconds longer on the last quiz, and in Activity Set #3 Student #3 spent 15 seconds longer completing the last quiz). The greatest difference between the time spent completing the first and the last quiz was 6 minutes 20 seconds by Student #4 in Activity Session #4.

The group average time for every quiz underneath the individual time can also be seen on Table 4-1. In order to simplify the analysis of the comparison of the first and last group average time in each strand a separate table has been constructed, Table 4-3. The average time needed by the group of five student participants to complete the first and final daily written quizzes for each activity set varies, as seen in Table 4-3. With the exception of Activity Set #2, for which the group average time increased by two seconds, the last quiz for eleven of the twelve Activity Sets was completed in less time than the first quiz. This reduction in group average time ranged from the least difference of 25 seconds in the last quiz average time for Activity Set #10 to the greatest difference of 4 minutes and 13 seconds for Activity Set #9. The two other activity sets that showed great reduction in time in completing the last quiz by the group were Activity Set #5 (4 minutes 2 seconds in reduced time), and Activity Set #4 (3 minutes 49 seconds in reduced time).

Table 4-3 Comparison of Group Average Time Spent on the First and Last Quiz

Strand	Activity Set Number	Time Spent on First Quiz (min:sec) (mean)	Time Spent on Last Quiz (min:sec) (mean)
Number	1	3:02	2:06
	2	1:05	1:07
	3	3:25	2:20
Patterns and Relations	4	6:33	2:44
	5	5:32	1:30
	6	2:17	1:18
	7	1:56	0:36
	8	1:38	0:55
Shape and Space	9	4:45	0:32
	10	4:47	2:20
Statistics and Probability	11	2:36	0:25
	12	2:47	1:01

Improvement in Accuracy and Speed

The findings of this study, as previously stated, were based on data collected on accuracy and speed. The students' written responses to the daily quizzes were the major source of data collection, and they clearly indicate that the student participants in this study showed an increased accuracy and speed in their replies to the designed questions. In addition, the data from the other sources (i.e., test results, survey responses, and observation notes) supported those findings.

Daily exposure to Oral Mathematics drill activities showed that Grade 9 students (Senior I) were able to increase accuracy and speed of their responses to various types of mathematics questions - not only facts and easily memorized simple or straightforward multi-digit numerical operations - when given the same set of oral mathematics drill activities over a 2 to 8 day period. As described in Chapter 3, each daily quiz consisted of 10 questions. The goal during these Oral Mathematics Drill Activities was to have each student reply to all 10 questions correctly and quickly. With the exception of one case (Student #4, Quiz #23), students did not get all 10 questions correct on the first quiz, but quite often did have all 10 questions correct on later quizzes. When adjusted for absences, the five student participants scored 10 out of a possible 10 points on 29 of the last 55 quizzes taken for each of the 12 Activity Sets. The daily quiz scores and the time records for all five students who took part in this research study showed an increase in their accuracy and speed with each activity. (To view complete data collected from the daily quizzes see Table 4-1.) The accuracy measure consisted of recording the number of correct replies of each student for each quiz. The speed was measured by recording the time it took each student to complete a quiz. By looking at the first and last quiz score for each section, we can observe the difference in the accuracy and speed for each student for each activity set. The increase was not the same for all students, nor was it equal all across the four strands of the mathematics curriculum. Nevertheless, an increase in both accuracy and speed is evident from Tables 4-2 and 4-3 which show the group average improvement in accuracy and the group average improvement in speed, respectively, from the first to the last quiz of the study (also shown in Figure 4-1 and Figure 4-2).

Figure 4-1. Group Average Improvement in Accuracy Between First and Last Quizzes.

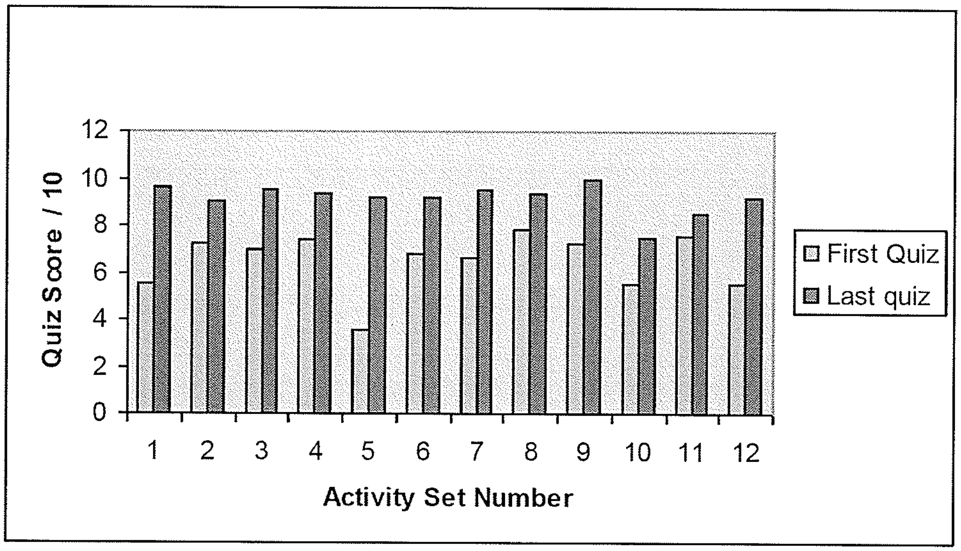
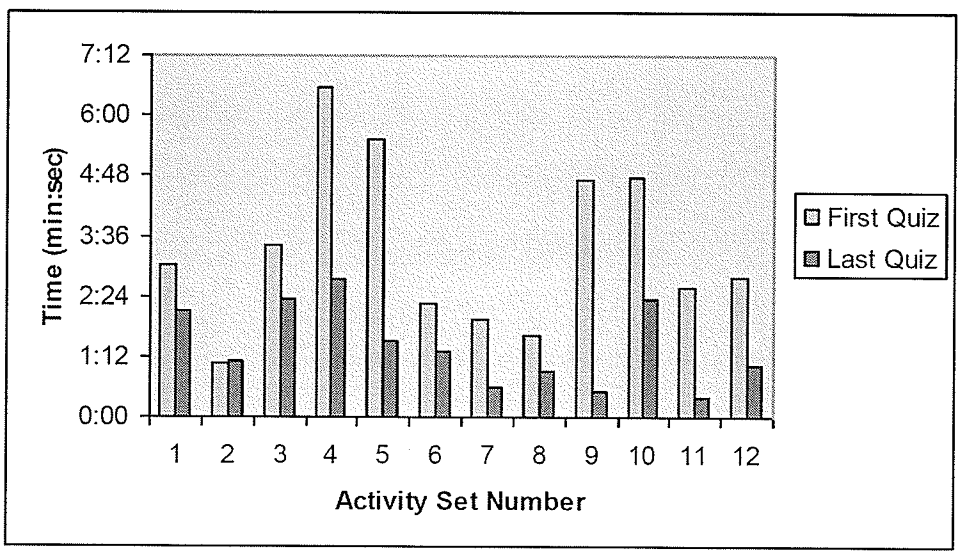


Figure 4-2. Group Average Improvement in Speed Between First and Last Quizzes.



The improvement was visible not only in the group average but also in individual cases. *All* students showed an increase in accuracy and speed. To make this case, I chose that data from a student participant who shows the least amount of increase in accuracy and speed namely, Student #4 (see Table 4-4). If we look at the first and last quiz scores for each set of activities for Student #4, we notice that this student did not achieve the same level of accuracy and speed in each activity set. Nevertheless, with the exception of Activity Sets # 8 and #10, the number of correct replies on the final quiz were higher than the number of correct replies on the first quiz in each activity set. The lowest number of correct replies on the first quiz was achieved in the Activity Set #1 (4 out of 10) and the highest number of correct replies on the first quiz was achieved in the Activity Set #8 (a perfect score of 10 out of 10). The lowest number of correct replies on the last quiz achieved by this student was in the Activity Set #10 (6 out of 10), and the highest number of correct replies on the last quiz was achieved in the Activity Sets #1, #4, #5, #6, and #7 (perfect scores of 10 out of 10). The highest increase in the scores between the first and the last quiz was 6, and this occurred in Activity Set #1. Along with showing increase in accuracy, the quiz data in Table 4-4 also display improvement in speed. With the exception of Activity Sets #6, the time spent completing the final quiz was less than the time spent completing the first quiz in each activity set (in 10 of the 11 cases since Student #4 did not complete the first quiz in Activity Set #10). The longest time spent on the first quiz was 9 minutes 10 seconds in the Activity Set #4, and the shortest time spent on the first quiz was 1 minute in the Activity Set #2. The longest time Student #4spent on the last quiz was 3 minutes 30 seconds in the Activity Set #10, and the shortest time spent on the last quiz was 40 seconds in the Activity Set #7. The greatest decrease in time spent between completing the first and the last quiz was 6 minutes 20 seconds in Activity Set #4, showing a great improvement in speed.

Table 4-4

Number of Correct Replies and the Time Spent Completing Each Quiz for Student #4

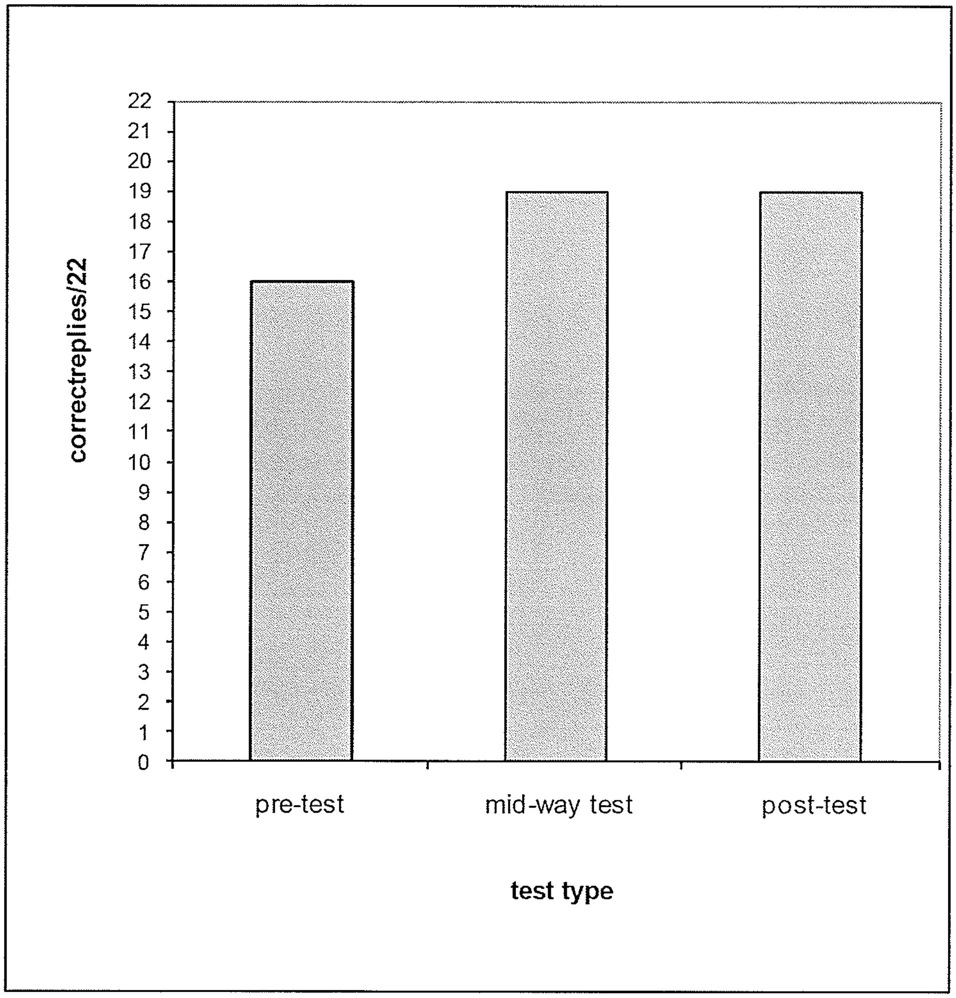
Strand	Activity Set Number	First Quiz Score/10	Last Quiz Score/10	First Quiz Time (min:sec)	Last Quiz Time (min:sec)
Number	1	4	10	3:20	1:20
	2	7	8	1:00	0:50
	3	8	9	2:55	1:25
Patterns and Relations	4	9	10	9:10	2:50
	5	4	10	4:50	1:30
	6	8	10	1:40	1:50
	7	7	10	2:00	0:40
	8	10	9	1:45	0:45
Shape and Space	9	8	8	5:00	1:10
	10	-	6	-	3:30
Statistics and Probability	11	6	9	3:50	0:50
	12	6	8	3:50	1:15

Quantitative Data Gathered from the Three Tests

Another source of quantitative data were the three researcher designed tests, i.e.; the pre, mid, and post test. Each test consisted of 22 questions, that were of the following types: (a) numerical questions, (b) pictorial representations, and (c) word problems. The test questions were similar to the quiz questions since they were both based on the same concepts, but they were not identical. There was a major difference in the way the tests were conducted in relationship to the quizzes. While the daily quizzes were written by the entire group at the start of each session, each of the three tests was conducted on individual bases and the questions were posed orally. To view the researcher designed tests see Appendix C, pp. 187-192.

Figure 4-3 shows results of the group average on accuracy based on the data obtained from the three researcher designed and audio-recorded tests. The pre-intervention test provided a group average of 16 correct responses out of the possible 22, the mid-way intervention test and the post-intervention test provided group averages of 19 correct responses out of the possible 22. The results represent an increase in accuracy by 14% between the pre-intervention and the mid-way intervention test but no increase between the mid-way intervention and the post-intervention test.

Figure 4-3. Comparison of Group Average Test Scores



To better understand the findings, the individual student accuracy and speed data are presented in Table 4-5. The lowest score on the pre-intervention test belongs to Student #1, who obtained 13 out of the possible 22, and the highest score belongs to Student #4, who obtained 18 out of the possible 22. The least amount of time spent replying to the pre-intervention test questions was 2 minutes 52 seconds by Student #1, and the longest amount of time was 5 minutes 15 seconds by Student #4. The lowest score on the mid-way through intervention test belongs to Student #4, who obtained 17 out of the possible 22, and the highest score belongs to Student #1, who obtained 21 out of the possible 22. The least amount of time spent replying to the mid-intervention test questions was 3 minutes 3 seconds by Student #3, and the longest amount of time was

Table 4-5 Comparison of Individual and Group Average Accuracy Scores and Time Spent on Replies to the Pre Mid way and Post Tests

Student	Pre-Test Score/22	Pre-Test Time (min:sec)	Midway Test Score/22	Midway Test Time (min:sec)	Post-Test Score/22	Post-Test Time (min:sec)
Number 1	13	2:52	21	4:19	-	-
Number 2	16	3:11	18	4:38	19	6:40
Number 3	17	2:53	19	3:03	18	4:56
Number 4	18	5:15	17	3:53	19	6:01
Number 5	17	3:08	20	4:15	20	6:55
Group Average	16.2	3:25	19	4:01	19	6:08

4 minutes 38 seconds by Student #2. The lowest score on the post-intervention test belongs to Student #3, who obtained 18 out of the possible 22, and the highest score belongs to Student #5, who obtained 20 out of the possible 22. The least amount of time spent replying to the prost-intervention test questions was 4 minutes 56 seconds by Student #3, and the longest amount of time was 6 minutes 55 seconds by Student #5.

Although data obtained from the tests indicate an increase in accuracy, they do not indicate an increase in speed as Table 4-5 indicates. In fact they show the opposite. One possible reason for the increase in time spent on a test could be the increase of the number of word problems (6 on the pre-, 8 on the mid-, and 12 on the post-intervention test) in comparison to the other two types of questions (numerical, and pictorial). Another possible reason for the increase in time spent on the tests could be the interjection of polynomials into the numerical portion of the mid- and post-intervention tests compared to the strictly arithmetic types of numerical questions on the pre-intervention test. A third possible reason for the increase in time spent on a test could be tiredness due to the increase in the number of after-school activities, and preparation for tests and exams. It is important to note that the pre-intervention test took place at the beginning of February right at the start of a new semester.

Automaticity and Conceptual Understanding

In this section I analyze and discuss data from the study that suggested that for some mathematical problems some students demonstrated *automatic* recall in their responses. Because of the questions involved, such automatic recall involved the understanding of mathematics concepts and not just basic facts. In their study, Cumming and Elkins (1999) refer to automaticity as "solution by fact recall or fast unconscious processing of the facts" (p.150). In the present study, I refer to automaticity not only as a fast recall of facts but also as quick processing of concepts where understanding is involved. The Oral Mathematics drill activities were based on questions involving conceptual understanding as I will demonstrate below.

Second, I analyze and discuss how the data support the claim of automaticity in participant students' responses to the quizzes, since the purpose of the study was to see if it was possible to increase accuracy and speed to the point of developing automaticity by using Oral Mathematics drill activities involving the understanding of mathematics concepts (and not just basic facts). Third, I analyze and discuss those data that do not support the claim of automaticity in student participants' responses.

Specific Support for the Claim of Improvement in Accuracy and Speed to the Point of Automaticity

It is important to note that during this three-month research study all five student participants showed significant increase in their accuracy and speed. For some students, I believe their progress in certain Oral Mathematics drill activity sets was to the point of automaticity or at least almost to the point of automaticity. As stated earlier, Cumming and Elkins (1999) refer to automaticity as "solution by fact recall or fast unconscious processing of the facts" (p.150). The present study takes this further by expanding the meaning of automaticity. Instead of talking of automaticity of basic-fact recall, the present study explores the possibility of automaticity involving mathematical understanding. As can be seen from Table 4-2 (p. 62), data collected from the daily written quizzes shows that the group average score for the last quizzes is greater than the group average score for the first quizzes in each activity block. In fact, for ten of the twelve drill activities, the group average score for the last quizzes is greater than 9 out of 10 possible correct replies. The data in Table 4-3 (p. 64) shows that the group average time spent on the last quiz is, for eleven of the twelve quizzes, 43 seconds to 4 minutes and 13 seconds less than the group average time spent on the first quizzes. In Activities 7, 9, and 11, the group average time spent on the last quizzes is 36, 32, and 25 seconds, respectively.

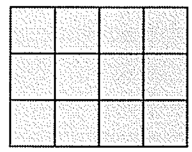
The data from one activity block (Shape and Space, activity block #9) suggest that students achieved automaticity. Figure 4-4 shows a sample quiz, which was given to the students during the study of activity block #9. In light of this data, the question that arises is as follows: Will the automatic response have involved conceptual understanding? The quizzes were not corrected during the sessions, and the students were not told which questions they replied to correctly. In order to correctly reply to the quiz questions, student participants needed to rely on the Oral Mathematics drill activities during which the concepts of perimeter and area were discussed. As previously described, the Oral Mathematics drill activities were only available to the students during the drill sessions at which time they had immediate oral feedback to their replies. Students had no access to the Oral Mathematics drill activities at any other time, nor would the activities on their own help them with correct replies, since there were no written replies provided at any time during the study. Therefore, I believe that the students had to have had *conceptual understanding* of area and perimeter of rectangles and had to have used that understanding in order to respond accurately and quickly to questions like #3 and #5 from quiz #28 (see Figure 4-4). Students have developed (deeper) conceptual understanding of the concepts involved in activity block #9. All questions in those quizzes were solved without the aid of a calculator, any manipulatives or written calculations.

Figure 4-4. Daily Quiz #28 based on Oral Mathematics Drill Activity #9 Shape and Space Strand.

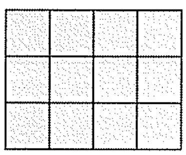
1. What is the total sum of the measure of the inside angles of a:

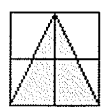
   triangle, ?

2. What is the measure of the third angle in a right triangle if the second known angle is: 72°

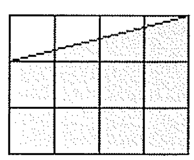
3. What is the perimeter of the following shape: 

4. How much will the perimeter of a rectangle increase if each length and width increases by:10

5. Determine the area of the following shape if each small square represents a square unit. 

6 Determine the shaded area of the following shape: 

7. How many right angles does a right-triangle have?

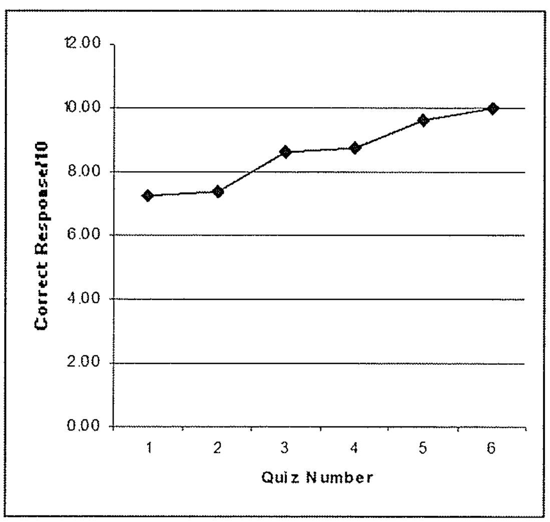
8. Determine the area of the following shape: 

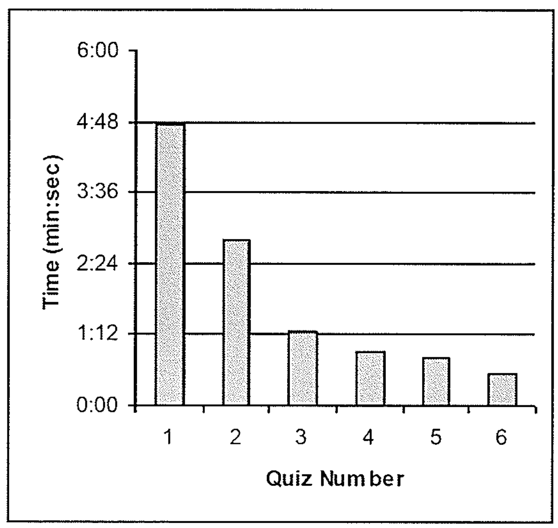
9. Determine the circumference of the circle if the radius is: 3 units long.

10. Determine the area of the circle (πr^2) if the radius is 5units long.

Automaticity was not achieved in all cases, but it was achieved in certain cases. Figures 4-5 and 4-6 and Figures 4-7 and 4-8 suggest the development of accuracy and speed up to automaticity for the respective activity blocks. Figures 4-5 and 4-6 provide a case for automatic responses (automaticity) for problems in activity block #9 by all student participants (based on group average). The graph in Figure 4-7 shows an increase in accuracy on daily quizzes from a single block (Activity Set #7) for Student #3 to the desired perfect score of 10 out of 10 and the maintenance of this accuracy for three consecutive quizzes. The graph in Figure 4-8 shows a decrease in the time it took Student #3 to complete each daily quiz for that block to a very desirable speed of 30 seconds,

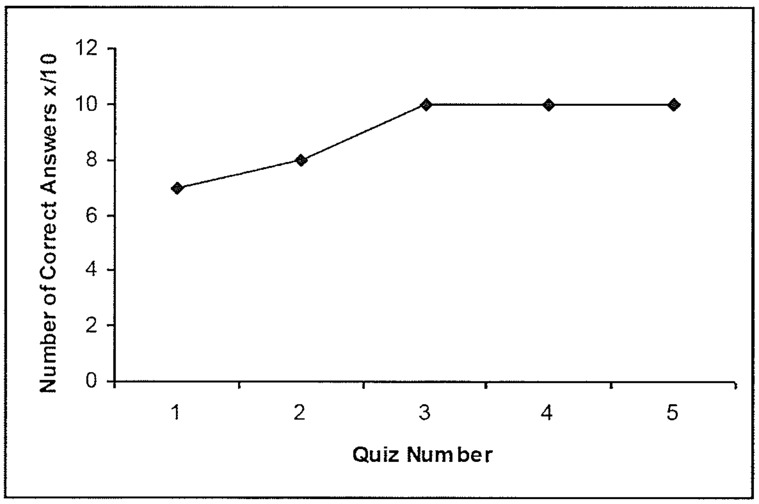
Figure 4-5 and Figure 4-6. Group Average Correct Quiz Response and Time to Questions Based on Activity No. 9 from the Shape and Space Strand.





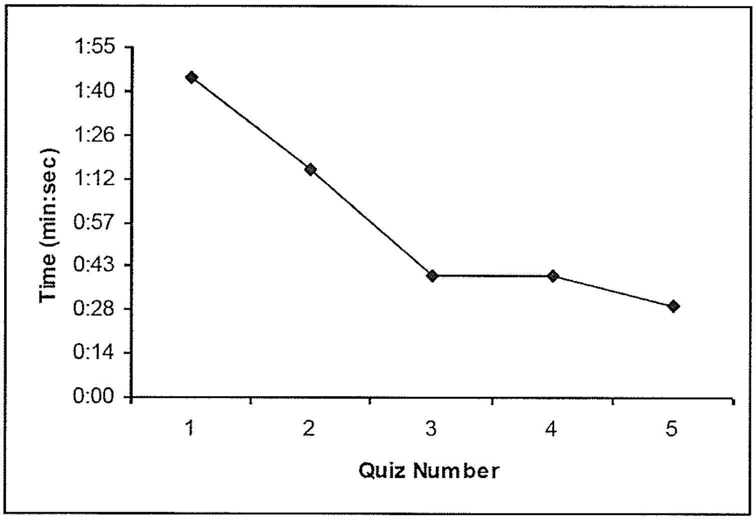
providing an average of 3 seconds per question. To appreciate this average of 3 seconds per question, we have to take into consideration that the questions on the quiz were not presented orally, but the students had to read each question first before writing a reply. In light of this fact, we can appreciate how quickly Student #3's mind must have worked in order to read and reply to 10 questions of the above described nature. Also, we must keep in mind that although the questions were identical on every quiz in one block the order of the questions, as previously stated, was different for each quiz. Therefore, the students could not simply memorize and write the answers in the same order but were required to read each question prior to writing a reply. In my view, Figures 4-7 and 4-8 provide evidence for Student #3's development of accuracy and speed up to automaticity for the problems in activity set #7.

Figure 4-7. Increase in Accuracy on Daily quizzes for Student #3 for Activity Set #7 from the Patterns and Relations Strand.



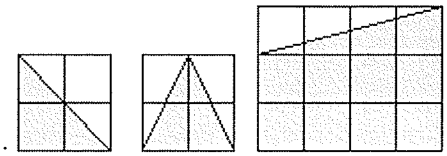
Conceptual understanding is the central piece of my study. Although it is not predominant due to the fact that the activities take a form of daily math drills, my study of Oral Mathematics is based on drill activities that involve conceptual understanding. All 120 of the Oral Mathematics drill activities are carefully built on Grade 8 concepts as earlier described, and they are built to promote improvement in accuracy and speed in student replies. Students answered the questions correctly most of the time. As long as

Figure 4-8. Decrease in Time Spent Completing Daily Quizzes for Student #3 for Activity Set #7 from the Patterns and Relations Strand.



students answered a question correctly, there were no explanations provided. When students gave an incorrect reply to a question, they were immediately corrected. If there were different replies from the group of student participants, they were collectively asked to think which answer was the correct one, which means that they were involved in building understanding of the concepts involved in the respective problem. Most of the time, after a quick reconsideration of the question, they had the correct reply, but there were also times when all five students or perhaps just one would ask for an explanation of the concepts involved in the problem. For example, some of the Oral Mathematics drill activities based on the Shape and Space Strand, such as those in Figure 4-9, presented some challenges the first day they were used. All five students were able to give correct replies to questions related to solving the area of a square or a rectangle, but some found it difficult to find the area of other shapes. As such, several days of repeated explanations were required.

Figure 4-9. Activity 8 from Activity Set # 9 based on the Shape and Space Strand.

8. Determine the shaded area of the following shapes: 

The activity in Figure 4-9 consists of three questions. All five students replied correctly to the first question, stating that the area of the shaded region was 2 square units. The second question required an explanation. I provided a pictorial explanation, showing them that they can make a vertical cut in the middle of the square and get two rectangles, two square units each. Then I asked them what the area of each rectangle was. They seemed to understand the problem, since I heard them all saying "It's OK" and some of them "It's one, so the shaded area of the shape is 2 units". I also challenged them to look at the shape and tell me what they noticed about each square. They seemed to have noticed that each square was split into 2 halves. For the third question I asked if they could see a rectangle in the shaded area. When they said "yes", I asked them what else they could see. When they said "two triangles", I asked how many square units the area of the shaded triangle was. When they said "two", I asked what they had to do to find the total shaded area. They apparently understood, because all five students replied in unison that the shaded area was ten square units. Through this intervention, student participants developed conceptual understanding, which in turn helped them to increase their accuracy and speed in responding to the problems in the quizzes of Activity Set #9. Figure 4-10 and Figure 4-11 provide information on the increase in accuracy and speed for each student during the block in which the aforementioned explanation took place. Although the concepts needed some explaining, three of the students completed all ten questions correctly within 30 seconds, one student completed all ten questions within 40 seconds and the slowest student took 1 minute and 10 seconds to complete eight questions correctly. For the problems in this activity set, the data suggest the development of automaticity of the response process. It should also be noted that due to the nature of the questions and due to the fact that the order of the questions was different in each quiz, conceptual understanding was necessary in order for the replies to be correct and increasingly quicker.

Figure 4-10. Accuracy Results for Each Student for Activity Set # 9 from the Shape and Space Strand.

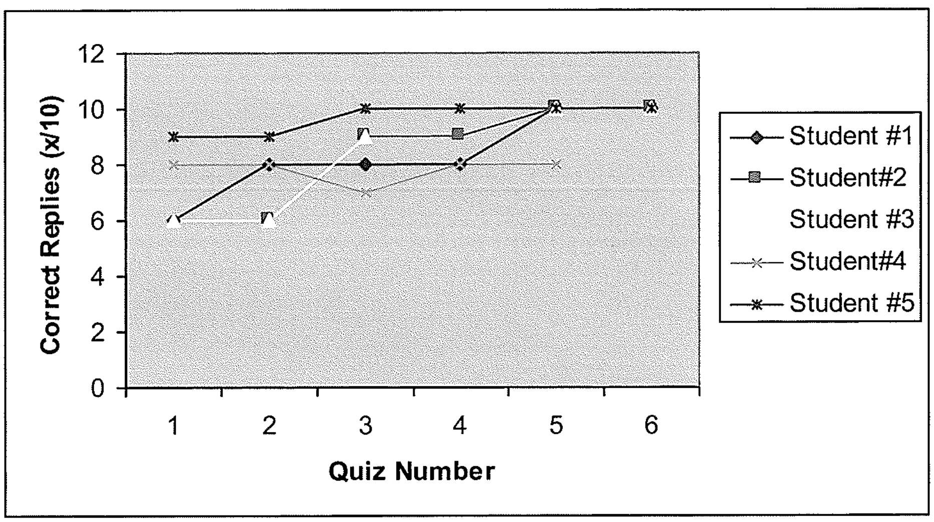
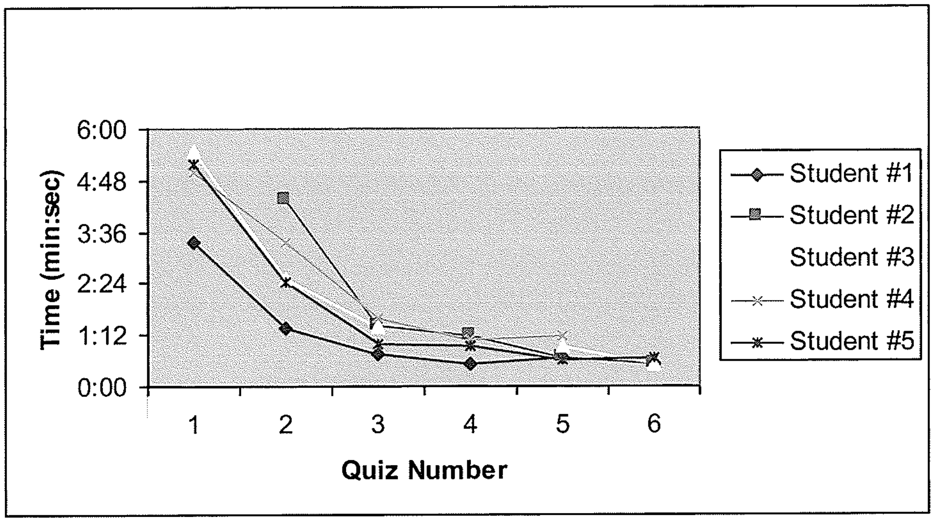


Figure 4-11. Results of Quiz Time for Each Student for Activity Set # 9 from the Shape and Space Strand.



To further discuss the relationship between automaticity and conceptual understanding, I am going to look at certain researcher designed *test* questions. Since the quiz questions previously discussed in this chapter were from the Shape and Space strand, I am going to comment particularly on the two test questions that were based on the same strand and taken from the researcher-designed post test. The two test questions are reprinted in Figure 4-12 (p. 82). The first of the two questions is based on the same concept as quiz question number 3 in Figure 4-4 (p. 75). The second of these post-test questions is based on the same concept as quiz question number 5 in Figure 4-4 (p. 75). Although the questions on the quiz and the test are based on the same concepts, respectively, they are very different in appearance. Each of the two quiz questions have a pictorial representation, while the test questions are strictly written without any pictorial representations, which means that during the post-test the students had to base their answers strictly on my oral questions. Had they not understood the concepts of perimeter and area, I believe, they would not have provided the correct oral response to the test questions. All five students replied correctly to both test questions as can be seen in Chapter 4 “Transcription Data from the Post-test”. Only when conceptual understanding is involved can students correctly reply orally to questions posed orally and without pictorial representations. This conceptual understanding of perimeter and area, as demonstrated in the test responses, must have been available to students when they demonstrated automaticity in their responses to the corresponding quiz questions.

Figure 4-12. Two Researcher Designed Test Questions Taken from the Post-test.

1. What is the perimeter of a 3m long and 5m wide room?
2. How many square feet of carpet do you need in order to cover the floor if your room is 9 feet wide and 11 feet long?

Data That Does Not Support a Claim of Automaticity

The research data from the daily written quizzes shows significant improvement in accuracy in students’ responses to Oral Mathematics drill questions. In many instances, students achieved perfect accuracy (10 out of 10) as seen in the examples in the previous section. The same data show, in most cases, a decrease in time spent (increase in speed) completing the quizzes in each set of Oral Mathematics drill activities. But there are also data which do not seem to support the claim of automaticity (see Figure 4-1). Why is it that for some students and some questions in this study we cannot make the claim of automaticity? In order to answer the question I will analyze and discuss the data more closely by looking at three specific cases where a claim of automaticity does not seem to be supported.

Case #1: The block of data showing the least support for automaticity comes from Oral Mathematics Activity Set # 10. These activities were based on the Shape and Space Strand. The most prominent issue in this block is that the data are incomplete, which begs the question: Why such a large number of missing data? Could the students have lost interest? Did the students purposefully stay away due to the difficulty of the concepts in these activities? This activity set, like Oral Mathematics Activity Set # 9, required some explanation of certain concepts. Only Student #2 achieved the required accuracy of 10 out of 10, but that student started out with a high accuracy level of 9 out of 10 and missed only the last quiz of eight for this Activity Set. Students #1, 3, and 5, who achieved accuracies of 8 out of 10, missed two, three, and four quizzes, respectively, and Student #4, who achieved 6 out of 10, was present for only the last of the eight quizzes. Absences were due to illness or involvement in other after-school activities not because of the difficulty level of the concepts.

Case #2: Quiz results in Figure 4-13 (p. 85), which are based on Oral Mathematics drill Activity Set # 5 from the Patterns and Relations Strand, show accuracy for the group average as well as for the student with the smallest increase in accuracy, from 4 out of 10 to 6 out of 10, and the student with the largest increase in accuracy, from 3 out of 10 to 10 out of 10. Figure 4-13 shows that for a majority of the students the accuracy level increased to 10 out of 10. We can see in Figure 4-14 (p. 85) that the least amount of time spent on a quiz was over one minute. In light of this data, the following question arises: Why is there such a big gap between the lowest and highest quiz score and why is there not a greater increase in speed? It is important to note that Student #3, who scored 6 out of 10 on the last quiz also received 9 out of 10 on the quiz that preceded it, which would make the gap not that large. Nevertheless, it suggests that that student had some difficulty with the questions. This perhaps points to the difficulty of the questions in this particular strand.

Most activities in this study, as stated earlier, required not just automatic retrieval but other processes based on conceptual understanding. Such were the questions based on the Patterns and Relations Strand, which were asked on Quiz #12, #13, and #14. One question, for example, required the students to analyze a pattern and then continue the pattern. Another question required the students to find the number that is one more than the triple of the term "8x". Such questions do not completely lend themselves to automaticity in the same sense as, for example, a simple addition fact might, but practicing them increases the speed at which a student might provide a correct answer for those questions. The graphs in Figures 4-13 and 4-14 (p. 85) show that there were only three quizzes in this block, which means that there were only three sessions. This might not have been enough time to develop automaticity; perhaps more sessions of Oral Mathematics drill activities would have lead to automaticity.

Figure 4-13. Quiz Accuracy for Oral Mathematics Drill Activity Set #5, Patterns and Relations Strand

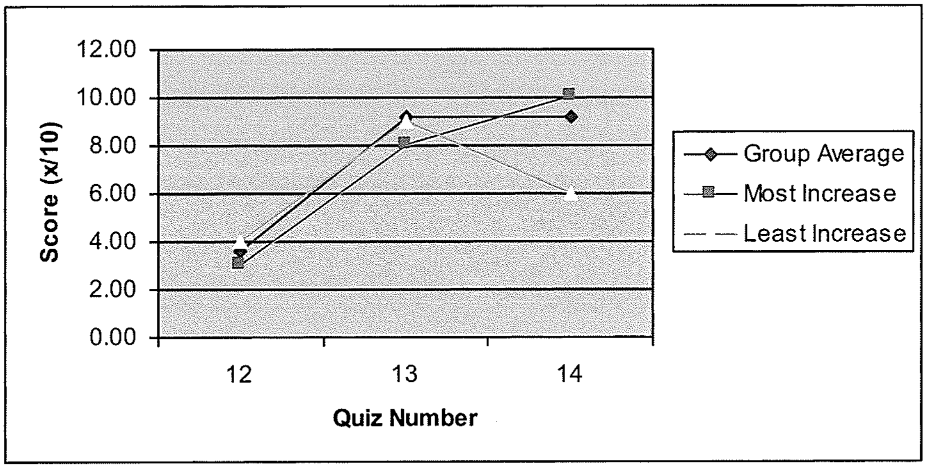
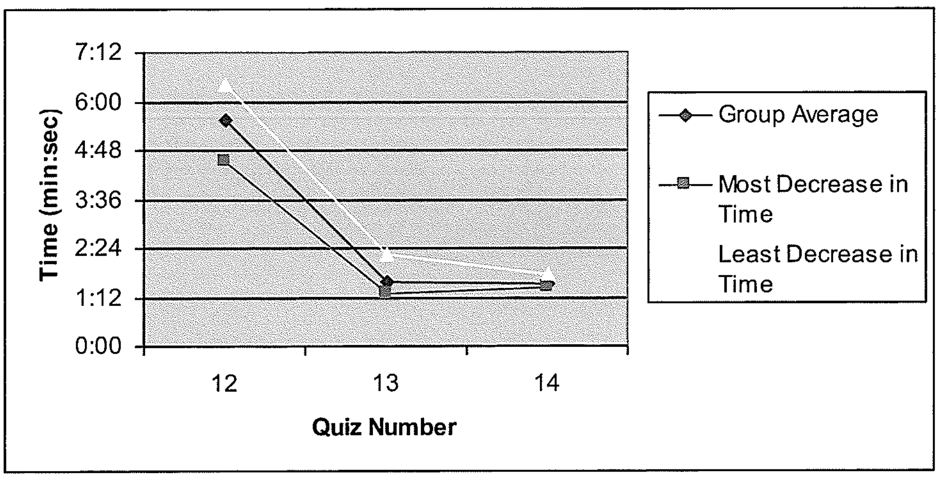


Figure 4-14. Quiz Speed for Oral Mathematics Drill Activity set #5, Patterns and Relations Strand



Case #3: The quiz results in Figure 4-15 (p. 86) are from Oral Mathematics drill Activity Set # 12 from the Statistics and Probability Strand and show accuracy results for each student. For three of the students, Students # 1, 2, and 3, the accuracy level increases to 10 out of 10, and for Students # 4 and 5 the accuracy level increases to 8 out of 10.

Figure 4-15. Quiz Accuracy for Oral Mathematics Drill Activity Set #12, Statistics and Probability Strand

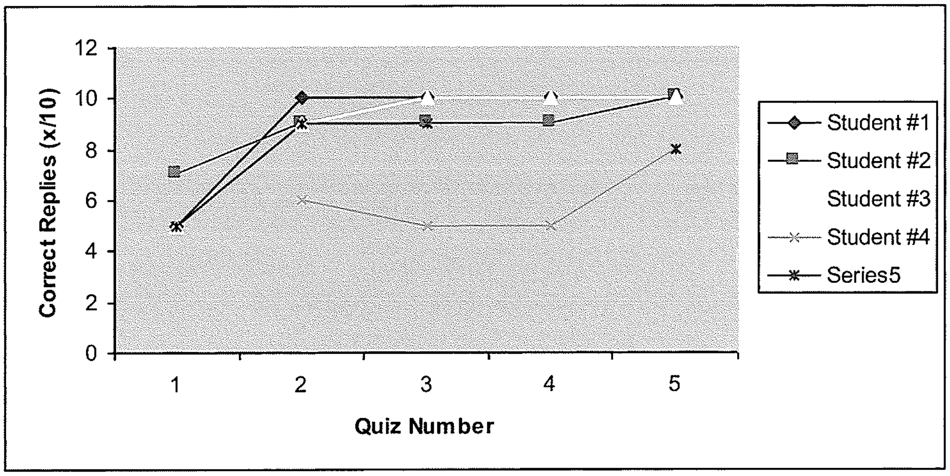
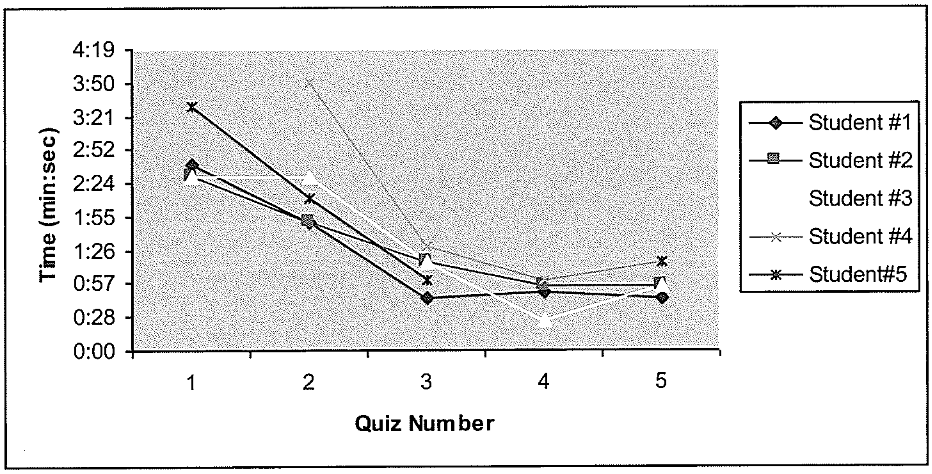


Figure 4-16 (p. 87) shows that 45 seconds was the least amount of time spent on a quiz. Some of the questions in this strand have more text than others (see Appendix A for the quiz questions), and the reading time, I believe, is one reason for the response time not decreasing further. Also, as in Case #2, this type of activity might require a longer period of time to become automatized. Due to the nature of these activities, I believe that 45 seconds for the 10 questions in this particular activity set is a sufficient speed for the students' responses to be considered automatized. The reason for my claim is that I believe that the length of time it took each student to read these questions also needs to be taken into consideration. Since each question on the quizzes had to be read by each student individually first and then the reply had to be written down, it is not possible to separate the time it took to read each question from the time it took to reply to it. Therefore the 45 seconds spent on a quiz does not mean that the student spent 45 seconds replying to the 10 questions, rather it means that it took 45 seconds to do the combination of both: the time it took to read the questions and the time it took to reply to the questions.

Figure 4-16. Quiz Speed from Oral Mathematics Drill Activity Set #12, Statistics and Probability Strand



Results based on data obtained from the researcher-developed tests do not indicate automaticity in replies to questions involving the understanding of mathematics concepts (and not just basic facts), since the results of the data did not show an increase in response speed. As previously mentioned, the level of difficulty of the three tests was not the same. Each test increased in difficulty. The pre-test was composed of six word problems, the mid-test was composed of eight, and the final-test was composed of twelve word problems. Since the questions on each test were new, the time it took to answer the word problems of each succeeding test would not necessarily decrease. A question can be raised here: "Was it a mistake to increase the number of word problems in each test?" The Oral Mathematics drill activities were designed to deal with previously learned concepts and were designed to increase accuracy and speed to the point of automaticity of student replies. Although the answer to a completely new word problem may not be automatic in the case of the test questions, the recognition of each concept in that question may be automatic.

This chapter dealt with the findings and the discussion of the quantitative data of the study. Chapter 5 will provide the findings and a discussion of the qualitative data.

CHAPTER 5:

FINDINGS FROM AND DISCUSSION OF QUALITATIVE DATA

In this chapter, qualitative data of the study will be presented and discussed. While the quantitative data collected in this research study on accuracy and speed were based primarily on the daily quizzes and secondarily on the transcripts of the researcher designed tests (pre-, mid-, and post-intervention), the qualitative data collected in this research study were based on the following three sources: (a) transcripts of the pre-, mid-, and post-intervention tests, which provided data on student participants' thought processes when responding to certain questions, (b) field notes, which provided data on the researcher's observations of certain students' replies or behavior during drill activities, and (c) survey responses, which provided data on student opinions on their own mathematical learning. Each qualitative data source will be discussed in the subsequent sections.

Qualitative Data Based on Test Transcripts

The transcripts of the recorded tests (pre-, mid-, and post-intervention), as stated above, provided some data on the nature of the student participants' replies and thought processes for certain questions. The data collected from the tests were coded such that they correspond to the nature of the question: (a) "N" for numerical, (b) "P" for pictorial, and "W" for word problems. The number of numerical (N) questions decreased with each test (12N, 10N, and 8N respectively), the number of pictorial (P) questions remained the same through all three tests (4P), and the number of word (W) problems increased with each test (6W, 8W, and 12W respectively). As well, it is worthwhile noting again that all test questions were posed orally by the researcher and all students replied orally. I noted also when a student requested to see a particular question in order to reply to it. Following are samples of qualitative data from each test I chose to discuss

Transcription Data from the Pre-test

Question: Tim has 8 kittens. He gave away 5 kittens last week and 3 kittens the week before last. How many kittens did he have originally?

> Student #1 "Originally he had 11, I think. The eight he gave away last week and the three the week before, that makes 11."
>
> Student #2 "Uh 16"
>
> Student #3 "Ah, he has 8, 8+5 equals 13, sixteen"
>
> Student #4 "Uh, 8, no. Can you repeat the question please? He had 8, oh O.K. so 16."
>
> Student #5 "(Pause) 19"

The sample above shows that out of the five student participants two provided an instant numerical reply (a correct reply by Student #2, and an incorrect reply by Student #5), two provided a reply followed by an explanation (a correct reply by Student #3, and an incorrect reply by Student #1), and one student participant (#4) provided an incorrect reply, immediately asked to have the question repeated and then provided a correct reply.

Question: How many uncles does Mona have, if her mother has 8 brothers and her father has 3 sisters?

Student #1 "8. All right, it depends if the sisters are married. So, 11 if the sisters are married."

Student #2 "Uh 3 uncles and 3 aunts. Can you repeat the question? Uh O.K. Uh 8. 8 uncles" (Me: Reason?) "Her mother has 8 brothers."

Student #3 "3 and O.K. 8 and 3, eleven uncles." (Me: How do you figure that. Give me the reason.) "O.K. because, her aunties might have married 3, and then her mom has 8 brothers and that's 11."

Student #4 "8 because it doesn't really say that... if her sister's are married. Then, she only has 8 uncles."

Student #5 "(Pause) How many uncles? 8" (Me: Your reason or logic for it?) "Because, her father only has sisters and her mother has the only uncles that she'll ever have."

The above question requires the student to think deeper than just calculating numbers (the reply will vary depending on whether or not the sisters are married). Three students (#2, #4 and #5) stated a correct reply and explanation based on the simplest meaning of the question, one student (#3) provided another correct reply based on a deeper meaning (the sisters are married and their husbands also become uncles), and one student (#1) provided 2 correct replies which the student based on two distinct possibilities (first – all three sisters are single, and second – all three sisters are married).

Transcription Data from the Mid-test

Question: How many $ will you need to add to $ 29 in order to buy a $ 45 jacket?

Student #1 "Let's see here. 45 minus 29, 35, 25, (accenting) 16"

Student #2 "45-29, uh, (Pause) Can you repeat the question?" (I repeated the question.) (Pause) "16 dollars."

Student #3 (Very quietly) "Uh, O.K. 1, 2, 15, 29, 45, 1," (Accenting) "16"

Student #4 "Uh 16."

Student #5 "Can you say that again? Sorry." (I repeated the question.) "Uh 16."

For this question the student needed to find only the difference of the numbers, which makes the question quite simple. One student (#4) provided a correct reply, two students (#1, and #3) did some quick oral calculations prior to giving a correct reply, and two students needed to have the question repeated prior to giving a correct reply.

Question: How can Mimi figure out her uncle's age, if she knows that 2 years ago he was 34 years old?

Student #1 "He is 36."

Student #2 "His uncle is 36 now."

Student #3 "Uh, 36. She can add 2 to 34 and she'll get 36."

Student #4 "She adds 2 to 34 which would be 36."

Student #5 "Uh, 2 years ago, he was how old?" (Me: 2 years ago, he was 34.) "Uh, 36."

For the above question all five students provided correct replies. Two students (#1 and #2) provided a reply and no explanation, two students (#3 and #4) provide a reply and an explanation, and one student (#5) needed to have the question repeated prior to providing a reply but no explanation.

Transcription Data from the Post-test

Question: There were 25 questions on the test. Walter got 80% of them correct. How many questions did he get correct?

Student #2 "Uh (Pause) I'm not sure." (I repeated the question.) "Um 80% of 25 so, Can I have paper please?" (Pause. Student writing) "Um, he got 20". (Me: 20 correct?) "Yah."

Student #3 "Uh (pause) uh 20 or wait, 22."

Student #4 "80 %? O.K. Um 80 divided by 20 (pause) 80 divided by 4 equals 20, because 4x25 equals 100. So 80 over 100." (Me: So your answer is? How many did he get correct?) "Twenty."

Student #5 (Pause) "25 questions?" (Me: Yes.) "Twenty."

The question is, I believe, a typical percentage mathematics question. The transcript shows that one student (#5) provided a correct reply after confirming the question, one student (#4) provided a correct reply after some oral calculations, one student (#2) provided a correct reply after some oral calculations but not before the question was repeated, and one student (#3) provided a correct reply only to change it instantly to an incorrect reply.

Question: Tom's mother is 30 years old and his father is 34 years old. Tom's age is the square root of his mother's and his father's age combined. How old is Tom?

Student #2 "Uh 8."

Student #3 "Um two ages combined. O.K. (pause) I don't know." (I read the question again.) "Oh, O.K. He is 8."

Student #4 (Pause) "The mother is 30. Oh 8."

Student #5 "The two ages combined? The square of those? (Me: the square root) "What were the ages again? 30. So 5. Five; and then the, no. So I do square root and then add or add and then square root? (Me: I can't tell you that. Sorry.) "Can I hear the question again?" (I repeated it.) "Oh, 8."

The above question was answered correctly by all four students. Two students (#2 and #4) provided a correct reply after hearing the question, two students (#3 and #5) provided a correct reply after having to hear the question a second time. Student #5 seemed to have a great deal of difficulty trying to figure out the answer prior to requesting the question to be repeated.

Question: Peter had 12 hockey sticks. How many hockey sticks would you say Peter gave away if he told you that he now has one third of the original amount?

Student #2 "Uh 4."

Student #3 "He has 4 left. So he gave away 8."

Student #4 "Peter had 12? O.K. He has 1/3 of the original amount left that would be 4 over 12 and he gave away 8."

Student #5 "How many hockey sticks?" (I repeated the question.) "He has one third left?" (Me: One third left. Yes.) "Uh 4." (Me: He gave away 4?) "Oh no. He gave away 8. He still has 4."

The above question seemed to have presented some difficulty to all students, because all students wanted to reply to what they thought the question was rather than the question that was posed. Student #2 stated the wrong reply without elaborating on it, Student #3 and #4worked out the correct answer orally, and Student #5 arrived at the correct reply through a dialogue with the researcher.

Question: There are 8 gift-baskets of apples, bananas and pears with the following label on each (5a + 3b + 4p). How many of each does the storekeeper need in order to fill all 8 baskets?

Student #2 "Can I see the question?" (Pause. Student looking at the question.) "Uh, uh 40a plus 24b plus 32p."

Student #3 "Can you repeat the question please?" (I repeated it.) "So, 5 apple, I don't know." (I showed the label to the student.) "Oh, so O.K., O. Ok. So he needs 40 apples 24 bananas and 32 pears."

Student #4 "Could you repeat the question please?" (I repeated it.) "How many of each? (pause) Oh 40 apples wait, 40 apples to fill up one basket and 24 bananas and wait; 40 apples 24 bananas and 32 pears."

Student #5 “Could you repeat that?” (I repeated it.) “What were the labels again? Sorry.” (Pause) “96 Uh, Can I see the label? What was after the tag?” “O.K. uh, 40 apples, (pause) 24 bananas and 32 pears.”

This particular question was difficult for all the students. All four students needed the question repeated. Student #2 needed to see the written question in order to provide a correct reply, Students #3 and #5 needed to see the label, which was a polynomial, in order to provide a correct reply. Judging by the number of pauses, questions, and requests for repetition, it can probably be concluded that this type of question does not lend itself well for oral testing.

Now, let us look at how the above stated chosen qualitative data based on the test transcripts support the research question “Can Oral Mathematics drill activities involving the understanding of mathematics concepts (and not just basic facts) be designed and implemented in a way that increases accuracy and speed to the point of automaticity?” In Chapter 4 the quantitative data obtained from the three tests (pre-, mid-way-, and post-intervention) indicate an increase in accuracy but they do not indicate an increase in speed as Table 4-5 indicates. In fact they show the opposite. As previously stated, one possible reason for the increase in time spent on a test could be the increase of the number of word problems (6 on the pre-, 8 on the mid-, and 12 on the post-intervention test) in comparison to the other two types of questions (numerical, and pictorial). This increase in the number of word problems is a very important factor to consider. It was not accidental but was an intentional design element placed in the tests by the researcher in order to test for conceptual understanding. Conceptual understanding, as earlier stated, is the central piece of this study. The difficulty level of the word problems also increased with each successive test as can be seen in the above qualitative data from the transcripts of the three tests. The pre-intervention test word problems were relatively simple and the student replies, although not all correct, were quick. The students seemed to have solved them easily. As the above qualitative data from the mid-way-through intervention test word problems demonstrate, this test was a bit more challenging than the pre-intervention test word problems, but the students still solved them with relative ease. The post-intervention test word problems were the most difficult. The above selected examples show that the students asked to have these questions repeated more often than the ones on the pre-intervention test or the questions on the mid-way-through test.

That the qualitative data above does not show an increase in speed in each successive test does not by itself defeat the success of the Oral Mathematics drill activities. The above chosen transcription data show that the students were able to solve the questions orally/mentally and were able to provide correct replies to the word problems in the post-test even when the word problem was complicated and required repeating as in the case of the last example from the post-test. The qualitative data provided above show that two students solved 3 out of the 4 selected word problems correctly (Student #2 and Student #3) and that two students solved all 4 out of the 4 selected word problems correctly (Student #4 and Student #5) providing a total of 14 correct replies out of the possible 16. Furthermore, it is important to note that, the word problems in the tests were not previously rehearsed problems but were completely new and specifically designed for each test. This means that the students would not have been able to solve the word problems correctly had they not understood the underlying concepts. Furthermore, it shows that the Oral Mathematics drill activities were designed and implemented in a way that increased accuracy and speed to the point of developing automaticity not in the word problems themselves but in the underlying concepts necessary to apply in order to solve the word problems.

Qualitative Data Based on Field Notes

Along with the quizzes, tests and survey questions I occasionally also wrote down some of my observations of: (a) the readily noticeable speed of the replies (slow or quick, as opposed to the actual time in minutes or seconds), (b) accuracy of the replies, (c) participation (the number of students that were replying), (d) uniformity (Did all five students reply at the same?), (e) peculiarities concerning a student, and (f) peculiarities concerning a drill session. These qualitative data were all for the purpose of supporting the quantitative data. Of special interest were student comments or questions during the Oral Mathematics drill activities, including: (a) the use of fingers, and (b) quick, barely audible counting (see the summary of selected observations below).

The first set of data from my field notes are from the Activity session after Quiz #5. This was the seventh time that I met each student that attended all four previous drill sessions. We met once during the time when the initial meeting took place and the survey questionnaires were filled in, we met for the second time when each audio-taped pre-intervention test was conducted, and we met four times for the drill sessions. By this session (seventh meeting but fifth drill session) the students heard me say many times that the correctness of their replies during the Oral Mathematics drill sessions will not have any consequences on their regular class mathematics grade and that it was, therefore, O.K. to call out a reply even if they were not sure of the correctness of their reply. I also believe that the students were starting to feel at ease with me. The observations that follow were based on those premises.

> "Number strand worksheet #3 was introduced (fractions: addition, subtraction, multiplication, and division).
>
> Students said the quiz was difficult.
>
> To ease the activities, we did pictorial representation of fractional operations.
>
> Student #1 was quiet throughout the entire time, seemed to be listening, watching, and absorbing.
>
> Student #2 was very excited about the activities and explanations. Later on Student #2 asked if you could use common denominators when you add and subtract.
>
> At the start of the activity session Student #4 asked if "of" means "multiply", then Student #3 said, "Oh! That's what that means."
>
> All four students were super eager to give responses. They all responded with excitement to the end.
>
> They all said: "Thank you." as they were leaving."
>
> (Field notes; activity session after Quiz #5; Student #5 was missing)

It is important to note that the above situation took place during a first day of a new drill session. The quiz, which the students said was difficult, was actually their introduction to those particular questions. The drill activities followed the quiz. The questions and comments that the students made during this session suggested to me that they were interested in learning.

The following field notes describe what I observed was the difference between a last day activity session and a first day activity session:

> "Activity set #4 does not seem to hold their interest any more."
>
> (Field notes; Activity session after Quiz #11; all five students were present)
>
> "Oral Mathematics activity set #5 seemed to have created new interest. All five students were interested in the activities and asked good questions. We discussed adding constant + constant vs. variable + constant."
>
> (Field notes; activity session after Quiz #12; all five students were present)

These examples suggest that students were interested in understanding and learning new material in mathematics (activity session after Quiz #12), and that when students understood and leaned the material that they were not interested in more repetition (activity session after Quiz #11). The next and last example I chose was not a regular activity session but rather a review session dealing strictly with word problems. This was the second last intervention session prior to the final individual testing, and survey.

"All questions were calculated orally/mentally. No pen (pencil), paper, calculator or any other devices were used by anyone.

Students #1 and #3 were competing – trying to outdo each other in speed.

Student #2 objected to the almost unrecognizable fast talk.

Students #4 and #5 started with a great speed but then gave up. They repeated the answers afterward.

Student #4 sometimes paused wanting more time processing the information.

Student #2 preferred a slower pace – time for processing information.

The students have seen these questions (questions 1 – 13) on previous activity sheets.

All replies were instant replies.

No quiz preceded this review session."

(Field notes; word problems–session 1; all five students were present)

This example suggests that all five students were quite comfortable with Oral Mathematics and it also suggests that all five students were quite comfortable with word problems, which is important to note for the purpose of this study.

How does the above sample of the qualitative data based on field notes help answering the research question? The following qualitative data selection based on the field notes display involvement of conceptual understanding during the Oral Mathematics drill activity sessions:

(1) "At the start of the activity session Student #4 asked if 'of' means 'multiply', then Student #3 said, "Oh! That's what that means." (Activity session after Quiz #5)

(2) "All five students were interested in the activities and asked good questions; we discussed adding constant + constant vs. variable + constant." (Activity session after Quiz #12)

The selected qualitative data based on field notes also suggests that automaticity was developed with concepts as well as with previously seen word problems: "The students have seen these questions (questions 1 – 13) on previous activity sheets. All replies were instant replies." (Word Problem session)

Qualitative Data Based on Survey Replies

Student participants' responses to the survey questions provided data on what the student participants thought about mathematics, their ability to learn mathematics, and the effects of the Oral Mathematics drill activities on their learning. The complete set of responses to the survey questions is provided in Appendix I (pp. 231-238). Here, I provide the responses to only those survey questions that deal specifically with the notion of accuracy and speed, since they are the two requirements for automatic replies.

Post-intervention survey question # 2: Did you find the Oral Mathematics drills helped improve your *accuracy* with simple operations? Why? Or Why not?

Student # 1 - "I would not know! I have no specific examples available to me, however, judging from the final test, I seem to be able to do word problems a bit more simple."

Student # 2 - "Yes it did because we were taught how to look at the problems differently which made it much easier."

Student # 3 - "Yes, because then you are mentally prepared and able to do them"

Student # 4 - "Yes, for the drills explained how to solve and understand a problem."

Student # 5 - "Yes, with some of the drills such as the % of a # it became easier in my daily life."

These data show that four of the five students found that Oral Mathematics drills helped improve their accuracy with simple operations. Student #1 did not know whether the drills helped or not. The statement "I have no specific examples available to me" made by student #1 was in reference to the fact that the daily quiz results were not available to the students and, therefore, they had no written proof of their progress as they were used to from their regular mathematics classes. In order to have a sense of their progress, the students had to rely on the feedback they received from me in response to their oral replies during the Oral Mathematics drill session. Our last two sessions, as mentioned earlier, were not regular Oral Mathematics drill sessions but were review sessions dealing with mathematics word problems, which I believe Student #1 was referring to when stating "however, judging from the final test, I seem to be able to do word problems a bit more simple".

Post-intervention survey question #3: Did you find the oral mathematics drills help improve your *speed* while performing simple operations? Why? Or Why not?

Student # 1 - "Not in particular since the tests required memorization due to repetition, and the overhead I think helped deform me. I was more for memorization and speed; not always for accuracy once I understood how something worked."

Student # 2 - "Yes because by doing the oral drills, it helped me think of it faster."

Student # 3 - "Yes, because you would be ready and to do it"

Student # 4 - "Yes for the repetition of the exercise helped to understand it better."

Student # 5 - "Yes with repetition it was easier to do all operations."

These data show that four of the five students found that Oral Mathematics drill activities helped improve their speed while performing simple operations. Student #1 did not share that belief but was rather confused, as seen by his or her statement "Not in particular since the tests required memorization due to repetition, and the overhead I think helped deform me. I was more for memorization and speed; not always for accuracy once I understood how something worked." I think it is important to note that Student #1 wanted to understand the mathematical concepts and provided replies based on those understandings. This statement most likely means that this student believed that his or her replies will be accurate once he or she understands the concepts; therefore the only concern is the speed at which the replies will be done. This seems to be the case because this student: (a) asked for clarification of concepts during the Oral Mathematics drill sessions, (b) received 10 out of 10 on five of the twelve final quizzes, when adjusted for absences, (c) received 7 out of 10 as his or her lowest score only once, and (d) stated on the final survey questionnaire that 80% to 90% of his or her homework is usually correct.

Examining how the above selected qualitative data based on the survey replies relate to the research question, we notice that the selected research questions themselves deal with the issues of accuracy and speed. The selected survey data reveal that 4 out of 5 students believed that the Oral Mathematics drill activities helped them improve their accuracy with simple operations, as well, 4 out of 5 students believed that the Oral Mathematics drill activities helped them improve their speed with simple operations. The one student (Student #1) who was somewhat confused also stated that he/she found solving word problems "a bit more simple", which to me suggests that the underlying concepts must have been understood by him/her better.

CHAPTER 6:

CONCLUSION

Answering the Research Question

The research question for the study was: Can Oral Mathematics drill activities involving the understanding of mathematics concepts (and not just basic facts) be designed and implemented in a way that increases accuracy and speed to the point of developing automaticity? In order to describe how the findings of this study answer the research question, we need to look at the complete daily quiz data (Table 4-1); the researcher's test recording based on the pre-, mid-way, and post-test (Chapter 5 and Appendix G); and the researcher's field notes (Chapter 5 and Appendix H).

Both quantitative and qualitative data show that the accuracy increased for all student participants as measured by the group average as well as for most individual participants (see Figure 4-1 for the group average improvement in accuracy between first and last quizzes, and see Figure 4-3 for the comparison of group average test scores; see Table 4-1 for the improvement in accuracy between first and last quiz score for individual students). Based on the research findings regarding accuracy, we can say that for this study Oral Mathematics drill activities involving the understanding of mathematics concepts (and not just basic facts) were designed and implemented in a way that increased accuracy in students' responses to orally presented problems from all four strands of the Manitoba mathematics curriculum.

Just as the findings showed increases in accuracy in most cases over a three-month period, they also showed decreases in the time students spent in completing quizzes but not in completing the tests (see Figure 4-2, p. 66 for group average improvement in speed between first and last quizzes, and see Table 4-5, p. 71 for the comparison of group average time spent on tests; see also Table 4-1, p. 58 to view the improvement in speed between first and last quiz score for individual students). Based on the research findings for speed, we can say that for this study Oral Mathematics drill activities involving the understanding of mathematics concepts (and not just basic facts) were designed and implemented in a way that increased speed.

If we take a closer look at the research findings regarding both accuracy and speed based on the daily quizzes, we can see that in certain cases and for certain students the time it took to complete a ten-question quiz accurately was as short as 20 seconds for a particular student (for details see Table 4-1, and Figures 4-7 and 4-8), and 25 seconds for the group average (see Table 4-3, and Figures 4-5 and 4-6). These times average to 2 seconds per question for a particular student and 2.5 seconds per question for the group average. This speed, I believe, demonstrated automaticity in responding, which Cumming and Elkins (1999) refer to as "solution by fact recall or fast unconscious processing of the facts" (p.150), and Woodward (2006) refers to as "the 3-second per fact criterion" (p. 286). Although the research data show that automaticity was achieved in certain cases, it was not achieved in all cases. In Case #1, when automaticity was not achieved, it was noted that student participants missed many sessions due to illness or due to involvement in other after-school activities. In case #2, there might not have been enough time to develop automaticity due to the fact that there were only three sessions in that particular activity block. In case 3, the nature of some of the questions required more reading time, and perhaps more repetition is needed in order to cause automatization. The questions that I asked the student participants during the study were based on Grade 8 concepts; to respond accurately to those questions, understanding was involved (not just basic facts; see Figure 4-4 for sample quiz questions, and Figure 4-12 for sample test questions taken from the Post-test). Yet on several occasions, the students gave a correct instant reply as the field notes show (see Chapter 5). The evidence for conceptual understanding is seen not only in the type of questions I posed but also in the numerous occasions the student participants asked for an explanation of the concept. Based on my research findings regarding accuracy and speed, I can state that for this study Oral Mathematics drill activities involving the understanding of mathematics concepts (and not just basic facts) were designed and implemented in ways that increased student accuracy and speed to the point of developing automaticity.

Within the limitations of the study (see next section in this chapter), the results of this study strongly suggest that Oral Mathematics drill activities can improve accuracy and speed, and that Oral Mathematics drill activities involving the understanding of mathematics concepts (and not just basic facts) can be designed and implemented in ways that increase accuracy and speed to the point of developing automaticity. This research study shows that the Oral Mathematics drill activities I created can help students learn to understand, remember and use mathematics concepts, and to perform accurate and quick mental calculations involving a wide range of concepts. Since the literature (Van de Walle and Folk, 2008, and.NRC, 2001) talks about procedural fluency being connected to conceptual understanding, Oral Mathematics drill activities may play an important role in mathematics learning in general. Drill activities practiced orally are not only part of the Oral Mathematics drill activities that I created but also are promoted by other researchers such as Hindy (2003) and Carraher, et al. (1987). The oral rehearsal in combination with the auditory memory aided in producing favourable results such as those presented in Tables 4-1 and 4-2. The results of this study in Oral Mathematics with Grade 9 (Senior 1) students strongly suggest that daily exposure to well designed Oral Mathematics drill activities can improve the accuracy as well as the speed of students' responses in mathematics. In so doing, they are a valuable part of mental mathematics. Oral Mathematics is a worthy activity to further explore with students possessing a range of mathematical abilities. It may be used as an aid in increasing students' rate of response to questions that can already be answered correctly and for improving accuracy with questions that students do not yet answer correctly. Indeed, Oral Mathematics provides a new way of designing and conducting mathematics drills.

Limitations of the Study and Future Research

This study has several inherent limitations. First, the research study was conducted after regular school hours. As a result of not being part of the required and regular classroom activities, attendance was strictly based on the good will of the participating students. Second, the small size of the study group limits generalization of the results of the study and the use of statistics to aid in making comparisons. Third, the self-selecting process for participation in this study resulted in participants who were all high achieving students of mathematics with a drive to self-improve. It is not known how average or low achieving students would have progressed or how an entire class of students with mixed achievement levels would have progressed had they been engaged in the same Oral Mathematics activities.

My study opens up important questions and suggestions for future research studies in Oral Mathematics, for example: Can Oral Mathematics drill activities involving the understanding of mathematics concepts (and not just basic facts) be designed and implemented in a way that increases accuracy and speed to the point of developing automaticity (1) in a variety of grade levels? (2) when the activities are conducted over a whole semester? (3) in a classroom of students with mixed achievement levels? (4) in a classroom of low achieving students?

In addition to these three questions, my study also opens up questions about the concept of automaticity. Woodward (2006) refers to automaticity in multiplication facts as "the 3-second per fact criterion" (p. 286). Future research should address the question whether a new definition of automaticity should be considered to account for automatization involving more complex questions dealing with algebraic and geometric concepts such as those presented in this study. Such consideration should include questions like 'Should the meaning of automaticity include meaning making?' 'What is the role of strategic thinking in automaticity?' and 'Should conceptual understanding be part of the definition of automaticity?'

Benefits of the Study

The findings of the study have benefits to mathematics education and teachers who consider mental mathematics an important part of their teaching of mathematics. The benefits for mathematics education are several. First, the data strongly suggest that certain concepts other than basic facts can be automatized. Second, the data suggest that a significant improvement in accuracy and speed can be achieved even with those types of questions which do not lend themselves to automaticity. Third, the data strongly suggest that well designed Oral Mathematics drill activities could be beneficial to students at a high school level.

This study of Oral Mathematics can be beneficial to teachers in the following way:

a. This study lets teachers know that concepts, not just facts, can be automatized.

b. This study lets teachers know that concepts at any grade level, not only the primary grades, can be automatized.

c. This study provides some guidelines on how to design Oral Mathematics drill activities. Reviewing the appropriate provincial Mathematics Curriculum Guide to view concept development across the grades is the first of six steps, and perhaps the most crucial one, for teachers to note. As well, special consideration should be given to all sample questions in Chapter 3 and the elimination of those that are unsuited to this type of an activity as described in Chapter 3.

d. This study provides some guidelines (described in Chapter 3) on how to implement Oral Mathematics drill activities.

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APPENDICES

Appendix A: Researcher Designed Daily Quizzes

Appendix B: Researcher Designed Oral Mathematics Drill Activities

Appendix C: Researcher Designed Tests

Appendix D: Researcher Designed Survey Questionnaires

Appendix E: Information Letters and Consent Forms

Appendix F: Quiz Date and Timeline

Appendix G: Test Transcripts and Test Codes

Appendix H: Field Notes

Appendix I: Survey Data and Coding

Appendix A:
Researcher Designed Daily Quizzes

Daily Quiz #1

based on Oral Mathematics Drill Activity Set #1 Number Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1 What s the expanded form of 5^2 ?.
2. What is the square of: 7 ?.
3. What is the square root of: 64 ?.
4. Estimate the square root of: 37 .
5. Estimate the square root of: 62 .
6. What is 10 % of: 150 ?.
7. What is 20 % of: 80.. ?
8. What is 30 % of: 70 ?
9. What is 5 % of: 120 ?
10. To make a tasty jug of iced tea, you need 7 measuring scoops of iced tea powder for every litre (L) of water. How many scoops of iced tea powder will you need for: 8L of water

Daily Quiz #2

based on Oral Mathematics Drill Activity Set #1 Number Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. What is the expanded form of 5^2 ?
2. Estimate the square root of: 37 .
3. Estimate the square root of: 62 .
4. What is 10 % of: 150 ?.
5. What is the square of: 7 ?
6. What is the square root of: 64 ?.
7. What is 5 % of: 120 ?
8. What is 30 % of: 70 ?
9. What is 20 % of: 80..?
10. To make a tasty jug of iced tea, you need 7 measuring scoops of iced tea powder for every litre (L) of water. How many scoops of iced tea powder will you need for: 8L of water

Daily Quiz #3

based on Oral Mathematics Drill Activity Set #2 Number Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. What is the square of: 10.
2. What is the square root of: 49 .
3. Convert to decimals: 2/10.
4. Convert to decimals: 10^{-2}.
5. Convert to fractions: 3.4
6. What is 10 % of: 150.
7. What is 20 % of: 80.
8. What is 30 % of: 120.
9. What is 5 % of: 80 .
10 Express in fractional form: 25%

Daily Quiz #4

based on Oral Mathematics Drill Activity Set #2 Number Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. What is the square of: 10.
2. What is the square root of: 49 .
3. What is 10 % of: 150.
4. What is 20 % of: 80.
5. What is 30 % of: 120.
6. What is 5 % of: 80 .
7. Convert to decimals: 2/10.
8. Convert to decimals: 10^{-2}.
9. Convert to fractions: 3.4
10 Express in fractional form: 25%

Daily Quiz #5

based on Oral Mathematics Drill Activity Set #3 Number Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1.	What is 1/2 of: 3/5
2.	What is 1/3 of: 3/7
3.	What is 2/3 of: 4/5.
4.	What is 1/4 of: 5/9
5.	What is 3/4 of: 3/4.
6.	Add 1/2 to: 3/5
7.	Subtract 1/2 from: 3/5
8.	Add 1/3 to: 1/2
9.	Subtract 1/3 from: 5/9
10.	How many 1/2 can you make from: 3/5

Daily Quiz #6

based on Oral Mathematics Drill Activity Set #3 Number Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1.	What is 1/2 of: 3/5
2.	Subtract 1/2 from: 3/5
3.	Add 1/2 to: 3/5.
4.	What is 1/4 of: 5/9
5.	What is 3/4 of: 3/4.
6.	What is 1/3 of: 3/7
7.	What is 2/3 of: 4/5
8.	Add 1/3 to: 1/2
9.	Subtract 1/3 from: 5/9
10.	How many 1/2 can you make from: 3/5

Daily Quiz #7

based on Oral Mathematics Drill Activity Set #3 Number Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1.	How many 1/2 can you make from: 3/5
2.	What is 1/3 of: 3/7
3.	What is 2/3 of: 4/5.
4.	What is 1/2 of: 3/5
5.	Subtract 1/2 from: 3/5
6.	Add 1/2 to: 3/5
7.	Subtract 1/3 from: 5/9
8.	Add 1/3 to: 1/2
9.	What is 1/4 of: 5/9
10.	What is 3/4 of: 3/4.

Daily Quiz #8

based on Oral Mathematics Drill Activity Set #3 Number Strand

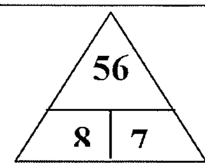
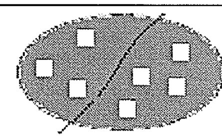
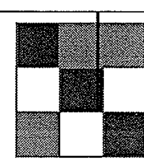
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1.	What is:	3/5 ÷ 1/2
2.	Add 1/2 to:	3/5
3.	Subtract 1/2 from:	3/5
4.	What is 2/3 of:	4/5
5.	What is 1/2 of:	3/5
6.	What is 1/4 of:	5/9
7.	What is 3/4 of:	3/4
8.	What is 1/3 of:	3/7
9.	Subtract 1/3 from:	5/9
10.	Add 1/3 to:	1/2

Daily Quiz #9

based on Oral Mathematics Drill Activity Set #4 Patters and Relations Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. Find the missing value in the ordered pair when y = 2x (7, _)
2. State the appropriate equations 
3. State the appropriate equations 
4. State the appropriate equations 
5. What is the Y-value of $Y = 7X$ for $X = 1$?
6. What is the Y-value of $Y = 2X + 5$ for $X = 0$?
7. What is the Y-value of $Y = 3X - 1$ for $X = 5$?
8. What is the Y-value of $Y = 10X^2$ for $X = 0$?
9. What is the Y-value of $Y = -X + 3$ for $X = 9$?
10. What is the Y-value of $Y = -X - 2$ for $X = 9$?

Daily Quiz #10

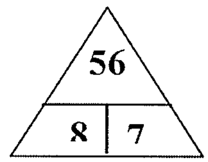
based on Oral Mathematics Drill Activity #4 Patterns and Relations

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation.

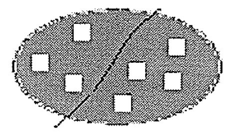
1. Find the missing value in the ordered pair when y = 2x

   (7, _)

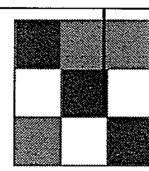
2. State the appropriate equations



3. .State the appropriate equations



4. .State the appropriate equations



5. What is the Y-value of $Y = 7X$ for $X = 1$?

6. What is the Y-value of $Y = 2X + 5$ for $X = 0$?

7. What is the Y-value of $Y = 3X - 1$ for $X = 5$?

8. What is the Y-value of $Y = 10X^2$ for $X = 0$?

9. What is the Y-value of $Y = -X + 3$ for $X = 9$?

10. What is the Y-value of $Y = -X - 2$ for $X = 9$?

Daily Quiz #11

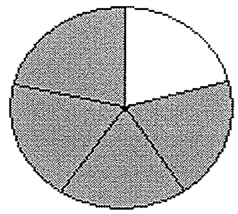
based on Oral Mathematics Drill Activity Set #4 Patters and Relations Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

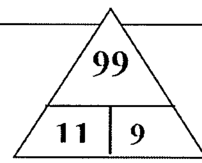
1. Find the missing value in the ordered pair when y = - 3 x + 2

   (7, _)

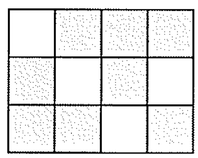
2. State the appropriate equations



3.. State the appropriate equations



4. .State the appropriate equations



5. What is the Y-value of $Y = 7X$ for $X = -2$?

6. What is the Y- of $Y = 2X - 11$ for $X = 0$?

7. What is the Y-value of $Y = 3X - 1$ for $X = 13$?

8. What is the Y-value of $Y = 10X^2$ for $X = 0$?

9. What is the Y-value of $Y = -X + 3$ for $X = 8$?

10. What is the Y-value of $Y - 3 = -X - 2$ for $X = 9$?

Daily Quiz #12

based on Oral Mathematics Drill Activity Set #5 Patters and Relations Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. How many years are four decades?

2. What is next in the pattern

   2, 1/2, 3, 1/3, 4, 1/4,

3. What is next in the pattern

   m+5, 3m+6, 6m+7, 10m+8,

4. What is next in the pattern

X	1	2	4	8	
Y	5	20	35	60	

5 Continue the pattern

   m^2+1, m^3+2, m^5+3, m^8+4,

6 . What is one half of: 600xy

7. What is 5 added to: 28xy

8. What is one more than the double of: 13t

9. What is one less than the triple of: 8w

10. State the number that is 3 more than half of: 10mn,

Daily Quiz #13

based on Oral Mathematics Drill Activity Set #5 Patters and Relations Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. What is next in the pattern

   2, 1/2, 3, 1/3, 4, 1/4,

2. What is next in the pattern

X	1	2	4	8	
Y	5	15	35	65	

3. What is next in the pattern

   m+5, 3m+6, 6m+7, 10m+8,

4. Continue the pattern

   m^2+1, m^3+2, m^5+3, m^8+4,

5. How many years are four decades?

6. What is one half of: 600xy

7. What is 5 added to: 28xy

8. What is one more than the double of: 13t

9. What is 3 more than half of: 10mn,

10. State the number that is one less than the triple of: 8w

Daily Quiz #14

based on Oral Mathematics Drill Activity Set #5 Patters and Relations Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. What is next in the pattern

X	1	2	4	8	
Y	5	15	35	65	

2. What is next in the pattern

   m+5, 3m+6, 6m+7, 10m+8,

3. What is next in the pattern

   2, 1/2, 3, 1/3, 4, 1/4,

4. Continue the pattern

   m^2+1, m^3+2, m^5+3, m^8+4,

5. How many years are four decades?

6. What is one half of: 600xy

7. What is 5 added to: 28xy

8. What is one less than the triple of: 8w

9. What is 3 more than half of: 10mn,

10. State the number that is one more than the double of: 13t

Daily Quiz #15

based on Oral Mathematics Drill Activity Set #6 Patters and Relations Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. How many years is a quarter of a century

2. Continue the pattern

   -2, -1/2, +3, +1/3, -4, -1/4, ___________

3. Continue the pattern

   4m+15, 9m-16, 16m+17, ___________

4. Continue the pattern

X	m	m^2	m^3	m^4	
Y	7	11	15	19	

5 Continue the pattern

   m^4+1, m^3+2, m^2+3, $m+4$, ___________

6. . What is one half of: 70xy

7. What is 7 added to: 56m

8. What is one more than the double of: 10t

9. What is one less than the triple of: 7w

10. State the number that is 3 more than half of: $82z^3$

Daily Quiz #16

based on Oral Mathematics Drill Activity Set #6 Patters and Relations Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. Continue the pattern

   -2, -1/2, +3, +1/3, -4, -1/4, ___________

2. Continue the pattern

   4m+15, 9m-16, 16m+17, ___________

3. Continue the pattern

X	m	m^2	m^3	m^4	
Y	7	11	15	19	

4. Continue the pattern

   m^4+1, m^3+2, m^2+3, $m+4$, ___________

5. What is 7 added to: 56m

6. What is one half of: 70xy

7. What is one more than the double of: 10t

8. State the number that is 3 more than half of: $82z^3$

9. What is one less than the triple of: 7w

10. How many years is a quarter of a century

Daily Quiz #17

based on Oral Mathematics Drill Activity Set #6 Patters and Relations Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. How many years is a quarter of a century

2. Continue the pattern

   -2, -1/2, +3, +1/3, -4, -1/4, __________

3. Continue the pattern

   4m+15, 9m-16, 16m+17, __________

4. Continue the pattern

X	m	m^2	m^3	m^4	
Y	7	11	15	19	

5 Continue the pattern

   m^4+1, m^3+2, m^2+3, $m+4$, __________

6. . What is one half of: 70xy

7. What is 7 added to: 56m

8. What is one more than the double of: 10t

9. What is one less than the triple of: 7w

10. State the number that is 3 more than half of: $82z^3$

Daily Quiz #18

based on Oral Mathematics Drill Activity Set #7 Patters and Relations Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. How many is a half: minute
2. Subtract 5y from: 2
3. Subtract 3z from: 9z
4. Add 8h to: 7h
5. Add 7c to: c+1
6. Add 3m to half of: 12m
7. Multiply by 7m: 6x
8. Multiply by 3x half of: 6
9. Divide by 3w: 7w
10. Divide by 5d: 3d

Daily Quiz #19

based on Oral Mathematics Drill Activity Set #7 Patters and Relations Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. Subtract 3z from: 9z
2. Subtract 5y from: 2
3. How many is a half: minute
4. Add 8h to: 7h
5. Add 7c to: c+1
6. Add 3m to half of: 12m
7. Multiply by 7m: 6x
8. Multiply by 3x half of: 6
9. Divide by 3w: 7w
10. Divide by 5d: 3d

Daily Quiz #20

based on Oral Mathematics Drill Activity Set #7 Patters and Relations Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. Add 8h to: 7h
2. Add 7c to: c+1
3. Add 3m to half of: 12m
4. How many is a half: minute
5. Subtract 5y from: 2
6. Subtract 3z from: 9z
7. Multiply by 7m: 6x
8. Multiply by 3x half of: 6
9. Divide by 3w: 7w
10. Divide by 5d: 3d

Daily Quiz #21

based on Oral Mathematics Drill Activity Set #7 Patters and Relations Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. Multiply by 7m:	6x
2. Multiply by 3x half of:	6
3. Subtract 3z from:	9z
4. Subtract 5y from:	2
5. Add 7c to:	c+1
6. Add 3m to half of:	12m
7. Add 8h to:	7h
8. Divide by 5d:	3d
9. Divide by 3w:	7w
10. How many is a half:	minute

Daily Quiz #22

based on Oral Mathematics Drill Activity Set #7 Patters and Relations Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. Divide by 5d: 3d
2. Divide by 3w: 7w
3. How many is a half: minute
4. Add 8h to: 7h
5. Add 7c to: c+1
6. Add 3m to half of: 12m
7. Multiply by 7m: 6x
8. Multiply by 3x half of: 6
9. Subtract 5y from: 2
10. Subtract 3z from: 9z

Daily Quiz #23

based on Oral Mathematics Drill Activity Set #8 Patters and Relations Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. Subtract 5y from: 5y-2
2. Subtract 3y from: 4y+2
3. Add 3z to: -4m+2
4. Add 8h to: -7h-5
5. Multiply by 7c: c+1
6. Multiply by 3m: 2m+6
7. Multiply by (-7m): 6x-6
8. Divide by 3x: 6
9. Divide by 4d: 3d+2
10. Divide by (-3g): 3g-3

Daily Quiz #24

based on Oral Mathematics Drill Activity Set #8 Patters and Relations Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. Add 3z to: -4m+2
2. Add 8h to: -7h-5
3. Subtract 5y from: 5y-2
4. Subtract 3y from: 4y+2
5. Multiply by 7c: c+1
6. Multiply by 3m: 2m+6
7. Multiply by (-7m): 6x-6
8. Divide by 3x: 6
9. Divide by 4d: 3d+2
10. Divide by (-3g): 3g-3

Daily Quiz #25

based on Oral Mathematics Drill Activity Set #8 Patters and Relations Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. Multiply by 7c: c+1
2. Multiply by 3m: 2m+6
3. Multiply by (-7m): 6x-6
4. Divide by 3x: 6
5. Divide by 4d: 3d+2
6. Divide by (-3g): 3g-3
7. Subtract 5y from: 5y-2
8. Subtract 3y from: 4y+2
9. Add 3z to: -4m+2
10. Add 8h to: -7h-5

Daily Quiz #26

based on Oral Mathematics Drill Activity Set #8 Patters and Relations Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. Multiply by 3m: 2m+6
2. Divide by 3x: 6
3. Add 3z to: -4m+2
4. Subtract 5y from: 5y-2
5. Multiply by 7c: c+1
6. Divide by 4d: 3d+2
7. Add 8h to: -7h-5
8. Subtract 3y from: 4y+2
9. Multiply by (-7m): 6x-6
10. Divide by (-3g): 3g-3

Daily Quiz #27

based on Oral Mathematics Drill Activity Set #8 Patters and Relations Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. Subtract 5y from: 5y-2
2. Subtract 3y from: 4y+2
3. Add 3z to: -4m+2
4. Add 8h to: -7h-5
5. Multiply by 7c: c+1
6. Multiply by 3m: 2m+6
7. Multiply by (-7m): 6x-6
8. Divide by 3x: 6
9. Divide by 4d: 3d+2
10. Divide by (-3g): 3g-3

Daily Quiz #28

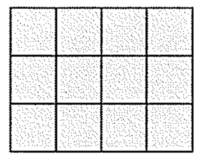
based on Oral Mathematics Drill Activity Set #9 Shape and Space Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

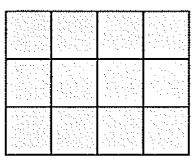
1. What is the total sum of the measure of the inside angles of a:

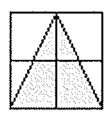
   triangle, ?

2. What is the measure of the third angle in a right triangle if the second known angle is: 72°

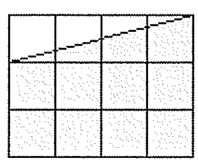
3. What is the perimeter of the following shape: 

4. How much will the perimeter of a rectangle increase if each length and width increases by:10

5. Determine the area of the following shape if each small square represents a square unit. 

6 Determine the shaded area of the following shape: 

7. How many right angles does a right-triangle have?

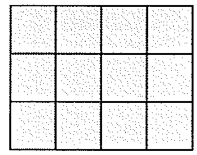
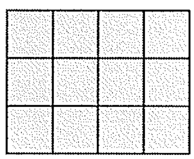
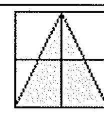
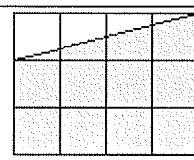
8. Determine the area of the following shape: 

9. Determine the circumference of the circle if the radius is: 3 units long.

10. Determine the area of the circle (πr^2) if the radius is 5units long.

Daily Quiz #29

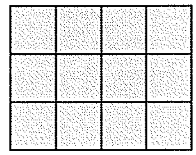
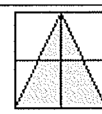
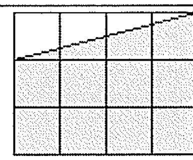
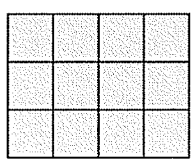
based on Oral Mathematics Drill Activity Set #9 Shape and Space Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. What is the perimeter of the following shape: 
2. How much will the perimeter of a rectangle increase if each length and width increases by: 10
3. What is the total sum of the measure of the inside angles of a triangle ?
4. What is the measure of the third angle in a right triangle if the second known angle is: 72°
5. Determine the area of the following shape if each small square represents a square unit. : 
6. Determine the are of the following shaded shape: 
7. Determine the area of the following shape: 
8. How many right angles does each 2D shape have: square, rectangle
9. Determine the circumference of the circle if the radius is: 3 units long.
10. Determine the area of the circle (πr^2) if the radius is 5units long.

Daily Quiz #30

based on Oral Mathematics Drill Activity Set #9 Shape and Space Strand

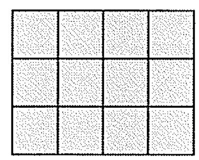
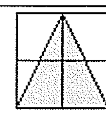
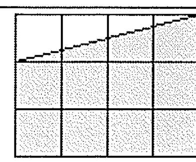
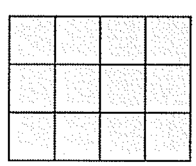
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. What is the perimeter of the following shape: 
2. How much will the perimeter of a rectangle increase if each length and width increases by: 10
3. How many right angles does each 2D shape have: square, rectangle
4. What is the total sum of the measure of the inside angles of a triangle ?
5. What is the measure of the third angle in a right triangle if the second known angle is: 72°
6. Determine the are of the following shaded shape: 
7. Determine the area of the following shape: 
8. Determine the area of the following shape if each small square represents a  square unit. :
9. Determine the circumference of the circle if the radius is: 3 units long.
10. Determine the area of the circle (πr^2) if the radius is 5units long.

Daily Quiz #31

based on Oral Mathematics Drill Activity Set #9 Shape and Space Strand

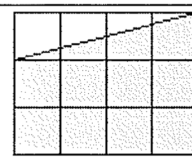
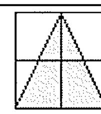
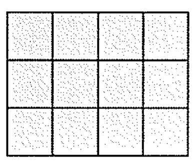
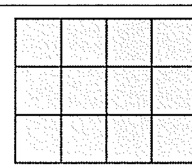
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. Determine the circumference of the circle if the radius is: 3 units long.
2. Determine the area of the circle (πr^2) if the radius is 5units long.
3. How many right angles does each 2D shape have: square, rectangle
4. What is the total sum of the measure of the inside angles of a triangle ?
5. What is the measure of the third angle in a right triangle if the second known angle is: 72°
6. How much will the perimeter of a rectangle increase if each length and width increases by: 10
7. What is the perimeter of the following shape: 
8. Determine the are of the following shaded shape: 
9. Determine the area of the following shape: 
10. Determine the area of the following shape if each small square represents a square unit. : 

Daily Quiz #32

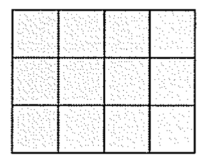
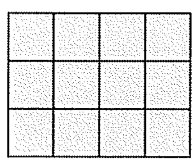
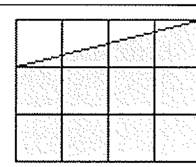
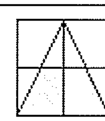
based on Oral Mathematics Drill Activity Set #9 Shape and Space Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1.	Determine the circumference of the circle if the radius is: 3 units long.
2.	How much will the perimeter of a rectangle increase if each length and width increases by: 10
3.	How many right angles does each 2D shape have: square, rectangle
4.	What is the total sum of the measure of the inside angles of a triangle ?
5.	What is the measure of the third angle in a right triangle if the second known angle is: 72°
6.	Determine the area of the circle (πr^2) if the radius is 5units long.
7.	Determine the area of the following shape: 
8.	Determine the are of the following shaded shape: 
9.	Determine the area of the following shape if each small square represents a square unit. : 
10.	What is the perimeter of the following shape: 

Daily Quiz #33

based on Oral Mathematics Drill Activity Set #9 Shape and Space Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1.	What is the total sum of the measure of the inside angles of a triangle ?
2.	What is the measure of the third angle in a right triangle if the second known angle is: 72°.
3.	How many right angles does each 2D shape have: square, rectangle
4.	How much will the perimeter of a rectangle increase if each length and width increases by: 10
5.	Determine the circumference of the circle if the radius is: 3 units long.
6.	Determine the area of the circle (πr^2) if the radius is 5units long
7.	What is the *perimeter* of the following shape: 
8.	Determine the *area* of the following shape if each small square represents a square unit. : 
9.	Determine the *area* of the following shape: 
10.	Determine the *area* of the following shaded shape: 

Daily Quiz #34

based on Oral Mathematics Drill Activity Set #10 Shape and Space Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

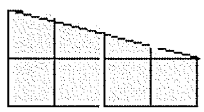
1. What is the measure of the third angle in a triangle if the other two angles are:

   69° and 40°

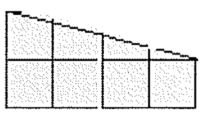
2. What is the length of the hypotenuse of the right triangle if the two sides are:

   7km and 4km

3. Determine the area of the following shape if each small square represents a square unit.

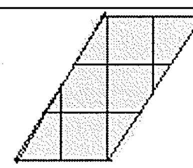
   

4. What is the perimeter of the following shape:

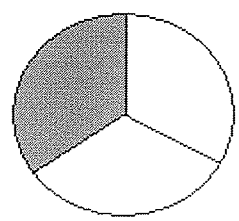
5. Determine the area of a triangle if the height is 7 cm and the base is

   9 cm,



6. Determine the area of each of the following shape:

7. What would the area of the above shape be if the base increased by7 units?



8. Determine the shaded area when the diameter is two units long.

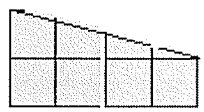
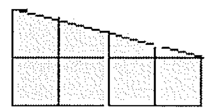
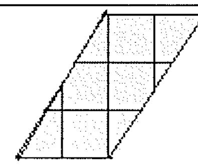
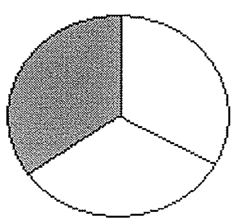
9. Determine the circumference of the circle if the diameter is: 8 units long.

10. Determine the area of the circle (πr^2) if the diameter is: 8 units long.

Daily Quiz #35

based on Oral Mathematics Drill Activity Set #10 Shape and Space Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. What is the measure of the third angle in a triangle if the other two angles are: 69° and 40°
2. What is the length of the hypotenuse of the right triangle if the two sides are: 7km and 4km
3. Determine the area of the following shape if each small square represents a square  unit.
4. What is the perimeter of the following shape: 
5. Determine the area of a triangle if the height is 7 cm and the base is 9 cm,
6. Determine the area of each of the following shape: 
7. What would the area of the above shape be if the base increased by7 units?
8. Determine the shaded area when the diameter is two units long.  :
9. Determine the circumference of the circle if the diameter is: 8 units long.
10. Determine the area of the circle (πr^2) if the diameter is: 8 units long.

Daily Quiz #36

based on Oral Mathematics Drill Activity Set #10 Shape and Space Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

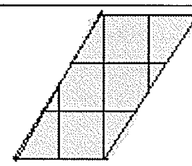
1. What is the length of the hypotenuse of the right triangle if the two sides are:

   7km and 4km

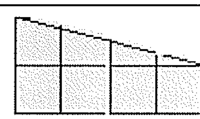
2. What is the measure of the third angle in a triangle if the other two angles are:

   69° and 40°

3. Determine the area of the following shape if each small square represents a square unit. 

4. Determine the area of the following shape: 

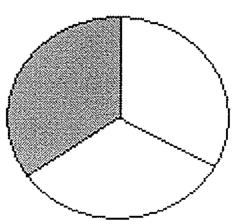
5. What would the area of the above shape be if the base increased by7 units?

6. What is the perimeter of the following shape: 

7. Determine the area of a triangle if the height is 7 cm and the base is

   9 cm,

8. Determine the shaded area when the diameter is two units long.


:

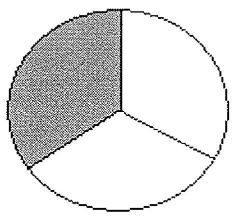
9. Determine the circumference of the circle if the diameter is: 8 units long.

10. Determine the area of the circle (πr^2) if the diameter is: 8 units long.

Daily Quiz #37

based on Oral Mathematics Drill Activity Set #10 Shape and Space Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. Determine the circumference of the circle if the diameter is: 8 units long.
2. Determine the area of the circle (πr^2) if the diameter is: 8 units long.
3. Determine the shaded area when the diameter is two units long.

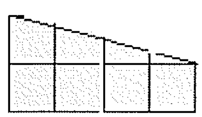


4. What is the measure of the third angle in a triangle if the other two angles are:

   69° and 40°
5. Determine the area of a triangle if

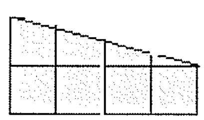
   the height is 7 cm and the base is 9 cm
6. What is the length of the hypotenuse of the right triangle if the two sides are:

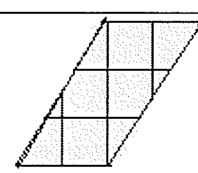
   7km and 4km
7. What is the perimeter of the following shape



8. Determine the area of the following shape if each small square represents a

   square unit





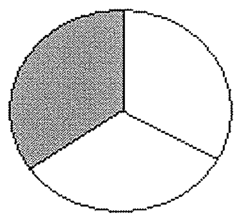
9. Determine the area of the following shape:
10. What would the area of the above shape be if the base increased by7 units?

Daily Quiz #38

based on Oral Mathematics Drill Activity Set #10 Shape and Space Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. Determine the circumference of the circle if the diameter is: 8 units long.
2. Determine the area of the circle (πr^2) if the diameter is: 8 units long.
3. Determine the shaded area of the circle when the diameter is two units long.

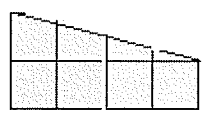


4. What is the measure of the third angle in a triangle if the other two angles are:

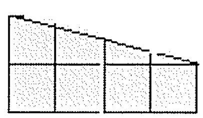
   69° and 40°
5. Determine the area of a triangle if

   the height is 7 cm and the base is 9 cm
6. What is the length of the hypotenuse of the right triangle if the two sides are:

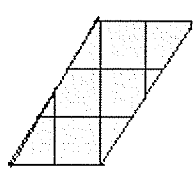
   7km and 4km
7. What is the perimeter of the following shape if the edge of each small square represents one unit?



8. Determine the area of the following shape if each small square represents a square unit.



9. Determine the area of the following shape if the edge of each small square represents one unit.



10. What would the area of the above shape be if the base increased by7 units?

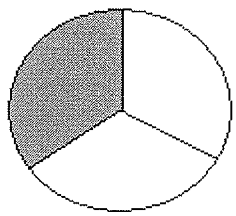
Daily Quiz #39

based on Oral Mathematics Drill Activity Set #10 Shape and Space Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1 Determine the area of the circle (πr^2) if the diameter is: 8 units long.

2. Determine the shaded area of the circle when the diameter is two units long.



3. Determine the circumference of the circle if the diameter is: 8 units long.

4. What is the length of the hypotenuse of the right triangle if the two sides are:

   7km and 4km

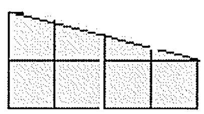
5. What is the measure of the third angle in a triangle if the other two angles are:

   69° and 40°

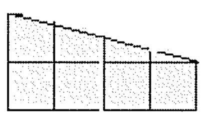
6. Determine the area of a triangle if

   the height is 7 cm and the base is 9 cm

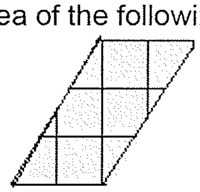
7. What is the perimeter of the following shape if the edge of each small square represents one unit?



8. Determine the area of the following shape if each small square represents a square unit.



9. Determine the area of the following shape if the edge of each small square represents one unit.

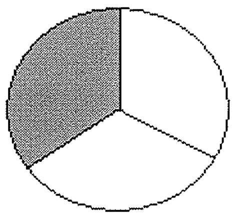
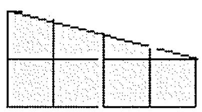
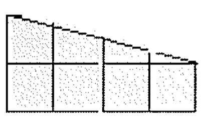
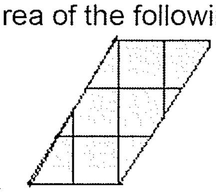


10. What would the area of the above shape be if the base increased by7 units?

Daily Quiz #40

based on Oral Mathematics Drill Activity Set #10 Shape and Space Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1 Determine the area of the circle (πr^2) if the diameter is: 8 units long.
2. Determine the shaded area of the circle when the diameter is two units long. 
3. Determine the circumference of the circle if the diameter is: 8 units long.
4. What is the length of the hypotenuse of the right triangle if the two sides are: 7km and 4km
5. What is the perimeter of the following shape if the edge of each small square represents one unit? 
6. Determine the area of a triangle if the height is 7 cm and the base is 9 cm
7. What is the measure of the third angle in a triangle if the other two angles are: 69° and 40°
8. Determine the area of the following shape if each small square represents a square unit. 
9. Determine the area of the following shape if the edge of each small square represents one unit. 
10. What would the area of the above shape be if the base increased by7 units?

Daily Quiz #41

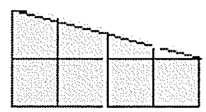
based on Oral Mathematics Drill Activity Set #10 Shape and Space Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1 What is the length of the hypotenuse of the right triangle if the two sides are:

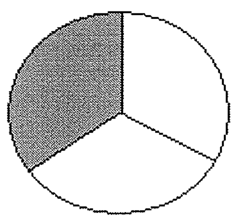
7km and 4km

2. What is the perimeter of the following shape if the edge of each small square represents one unit?



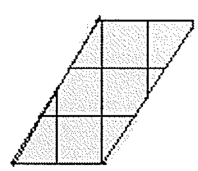
3. Determine the area of the circle (πr^2) if the diameter is: 8 units long.

4. Determine the shaded area of the circle when the diameter is two units long.:



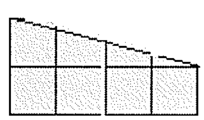
5. Determine the circumference of the circle if the diameter is: 8 units long.

6. Determine the area of the following shape if the edge of each small square represents one unit.



7. What would the area of the above shape be if the base increased by7 units?

8. Determine the area of the following shape if each small square represents a square unit.



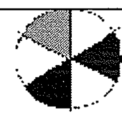
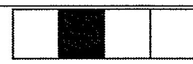
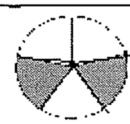
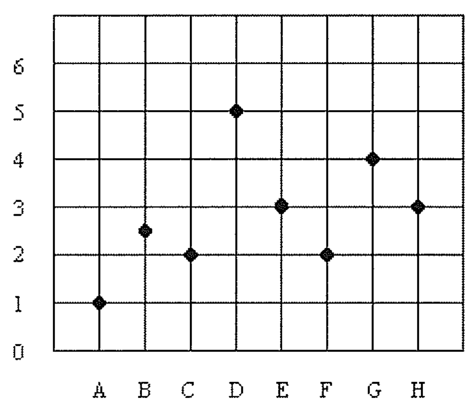
9. Determine the area of a triangle if the height is 7 cm and the base is 9 cm

10. What is the measure of the third angle in a triangle if the other two angles are:

69° and 40°

Daily Quiz #42

based on Oral Mathematics Drill Activity Set #11 Statistics and Probability Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. How could you express the following numbers out of a hundred? If you hear on the news that a certain political candidate has a 28% change of winning
2. How would you express the above number in decimals?
3. Express as a fraction: 10%
4. Express as a decimal: 15%.
5. Express as a decimal: 10% of 20.
6. Express the shaded area as a percentage. 
7. Express the shaded area as a fraction. 
8. Express the shaded area as a decimal. 
9 What is your chance of becoming the winner of a singing contest, if including you there are: 60 people entering?
10. What fraction of dots on this graph represents: more than 3 ? 

Daily Quiz #43

based on Oral Mathematics Drill Activity Set #11 Statistics and Probability Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

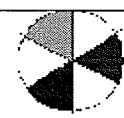
1. Express as a fraction: 10%

2. Express as a decimal: 15%.

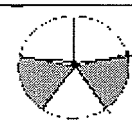
3. How could you express the following numbers out of a hundred? If you hear on the news that a certain political candidate has a 28% change of winning

4. How would you express the above number in decimals?

5. Express as a decimal: 10% of 20.

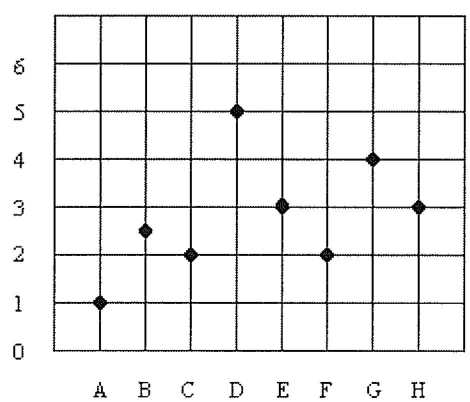
6. Express the shaded area as a percentage. 

7. Express the shaded area as a fraction. 

8. Express the shaded area as a decimal. 

9 What is your chance of becoming the winner of a singing contest, if including you there are:
60 people entering?

10. What fraction of dots on this graph represents: more than 3 ?



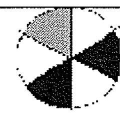
Daily Quiz #44

based on Oral Mathematics Drill Activity Set #11 Statistics and Probability Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. How could you express the following numbers out of a hundred? If you hear on the news that a certain political candidate has a 28% change of winning

2. How would you express the above number in decimals?

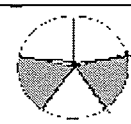
3. Express the shaded area as a percentage. 

4. Express as a decimal: 15%.

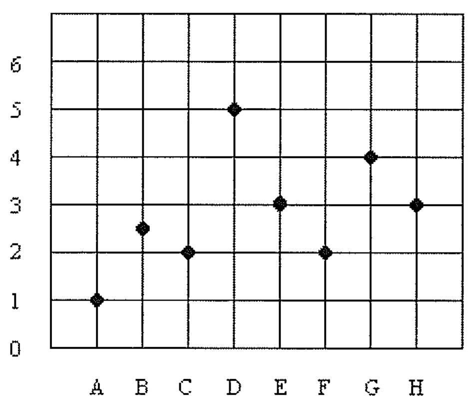
5. Express as a fraction: 10%

6. Express as a decimal: 10% of 20.

7. Express the shaded area as a fraction. 

8. Express the shaded area as a decimal. 

9 What fraction of dots on this graph represents: more than 3 ?

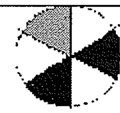


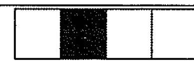
10. What is your chance of becoming the winner of a singing contest, if including you there are:

60 people entering?

Daily Quiz #45

based on Oral Mathematics Drill Activity Set #11 Statistics and Probability Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

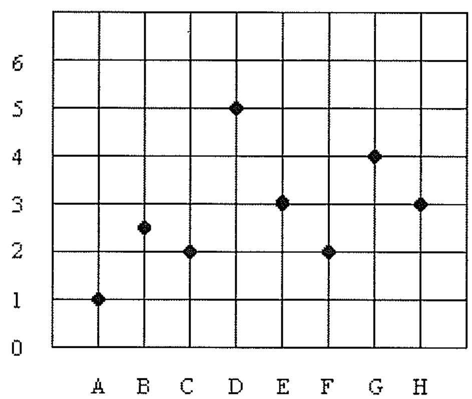
1. Express the shaded area as a percentage. 

2. Express the shaded area as a fraction. 

3. Express as a fraction: 10%

4. Express as a decimal: 15%.

5. What fraction of dots on this graph represents: more than 3 ?

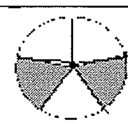


6. How could you express the following numbers out of a hundred? If you hear on the news that a certain political candidate has a 28% change of winning

7. How would you express the above number in decimals?

8. What is your chance of becoming the winner of a singing contest, if including you there are:
60 people entering?

9 Express as a decimal: 10% of 20.

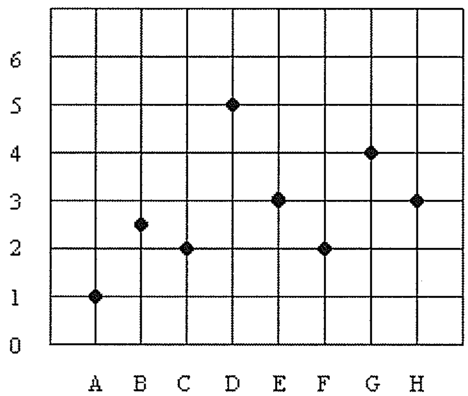
10. Express the shaded area as a decimal. 

Daily Quiz #46

based on Oral Mathematics Drill Activity Set #11 Statistics and Probability Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. What fraction of dots on this graph represents: more than 3 ?



2. Express as a decimal: 15%.

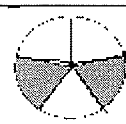
3. Express as a fraction: 10%

4. Express the shaded area as a fraction. 

5. How could you express the following numbers out of a hundred? If you hear on the news that a certain political candidate has a 28% change of winning

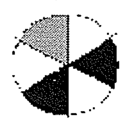
6. How would you express the above number in decimals?

7. Express as a decimal: 10% of 20.

8. Express the shaded area as a decimal. 

9 What is your chance of becoming the winner of a singing contest, if including you there are:

60 people entering?

10. Express the shaded area as a percentage. 

Daily Quiz #47

based on Oral Mathematics Drill Activity Set #12 Statistics and Probability Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. Which measure of central tendency should you use to find the average of the following sets of data: 9, 8, 8, 5, 7, 8

2. Find the average of the above set of data using the appropriate measure of central tendency.

3. Find the average: 30%, 50%

4. Find the mean: 15%, 20%, 25%

5. Find the mean: 3, 5, 5, 9, 4,

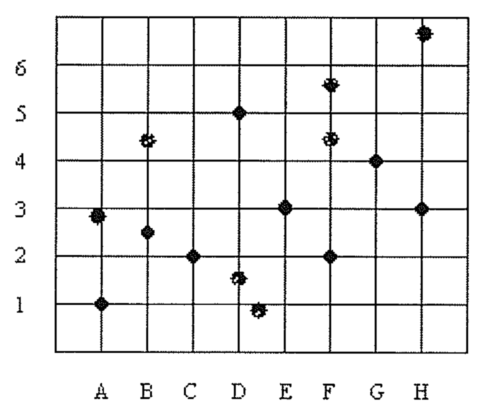
6. There were 4 yellow, 4 blue, 2 purple, 5 green and 3 red candies in the bag of candies you got for Easter. What is the probability of your first candy being: green, ?

7 If your first candy was green, what is the probability of your second candy being: green, ?

8. What is your chance of becoming the winner of a singing contest, if including you there are: 235 people entering

9. State as a percent 0.98,

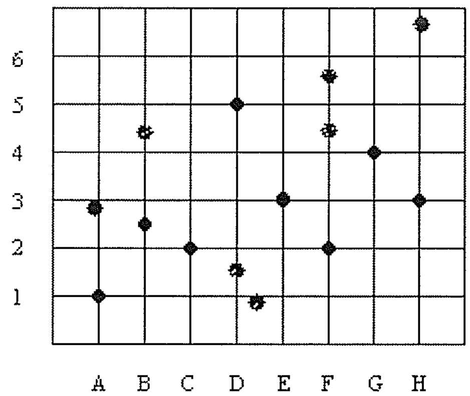
10. What fraction of dots on this graph represents: 4



Daily Quiz #48

based on Oral Mathematics Drill Activity Set #12 Statistics and Probability Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. What fraction of dots on this graph represents: 4 
2. State as a percent 0.98
3. Which measure of central tendency should you use to find the average of the following sets of data: 9, 8, 8, 5, 7, 8
4. Find the average of the above set of data using the appropriate measure of central tendency.
5. Find the mean: 3, 5, 5, 9, 4,
6. There were 4 yellow, 4 blue, 2 purple, 5 green and 3 red candies in the bag of candies you got for Easter. What is the probability of your first candy being: green, ?
7 If your first candy was green, what is the probability of your second candy being: green, ?
8. What is your chance of becoming the winner of a singing contest, if including you there are: 235 people entering
9. Find the average: 30%, 50%
10. Find the mean: 15%, 20%, 25%

Daily Quiz #49

based on Oral Mathematics Drill Activity Set #12 Statistics and Probability Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. Which measure of central tendency should you use to find the average of the following sets of data: 9, 8, 8, 5, 7, 8

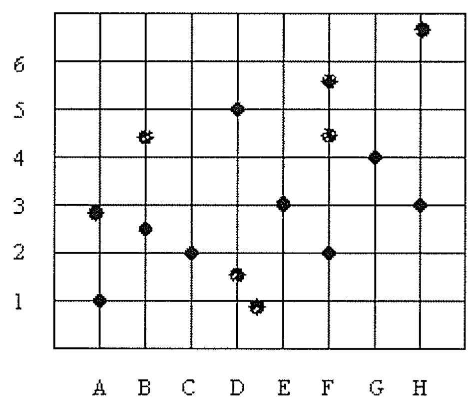
2. Find the average of the above set of data using the appropriate measure of central tendency.

3. Find the average: 30%, 50%

4. Find the mean: 15%, 20%, 25%

5. Find the mean: 3, 5, 5, 9, 4,

6. What fraction of dots on this graph represents: 4



7 State as a percent 0.98

8. What is your chance of becoming the winner of a singing contest, if including you there are: 235 people entering

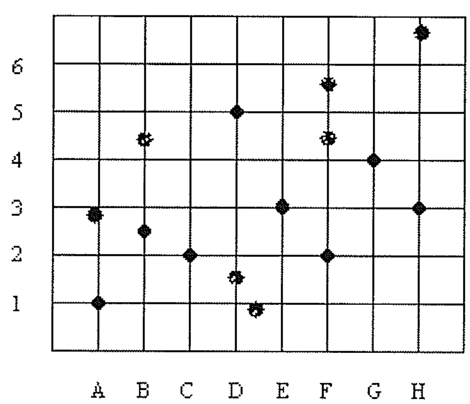
9. There were 4 yellow, 4 blue, 2 purple, 5 green and 3 red candies in the bag of candies you got for Easter. What is the probability of your first candy being: green?

10. If your first candy was green in the above question, what is the probability of your second candy being: green?

Daily Quiz #50

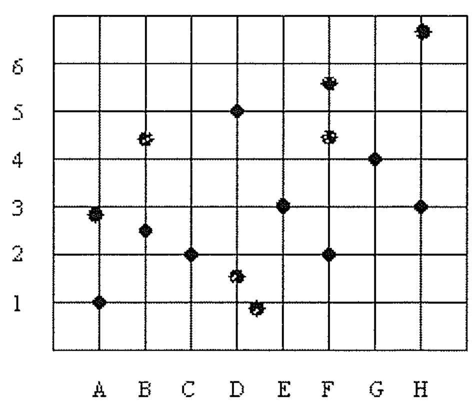
based on Oral Mathematics Drill Activity Set #12 Statistics and Probability Strand

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. Which measure of central tendency should you use to find the average of the following sets of data: 9, 8, 8, 5, 7, 8
2. Find the average of the above set of data using the appropriate measure of central tendency.
3. State as a percent 0.98
4. Find the average: 30%, 50%
5. Find the mean: 3, 5, 5, 9, 4
6. Find the mean: 15%, 20%, 25%
7. What is your chance of becoming the winner of a singing contest, if including you there are: 235 people entering
8. There were 4 yellow, 4 blue, 2 purple, 5 green and 3 red candies in the bag of candies you got for Easter. What is the probability of your first candy being: green?
9. If your first candy in the above question was green, what is the probability of your second candy being: green?
10. What fraction of dots on this graph represents: 4 

Daily Quiz #51

based on Oral Mathematics Drill Activity Set #12 Statistics and Probability Strand
All questions are to be solved without the aid of a calculator, any manipulative object or written calculation

1. There were 4 yellow, 4 blue, 2 purple, 5 green and 3 red candies in the bag of candies you got for Easter. What is the probability of your first candy being: green?
2. If your first candy in the above question was green, what is the probability of your second candy being: green?
3. State as a percent 0.98
4. What is your chance of becoming the winner of a singing contest, if including you there are: 235 people entering
5. Which measure of central tendency should you use to find the average of the following sets of data: 9, 8, 8, 5, 7, 8
6. Find the average of the above set of data using the appropriate measure of central tendency.
7 What fraction of dots on this graph represents: 4 
8. Find the average: 30%, 50%
9. Find the mean: 15%, 20%, 25%
10. Find the mean: 3, 5, 5, 9, 4

Word Problem Quiz

based on Oral Mathematics Drill Activity **Word problems**

All questions are to be solved without the aid of a calculator, any manipulative object or written calculation.

1. What is your chance of becoming the winner of a singing contest, if including you there are 60
2. What is the length of the hypotenuse of the right triangle if the two sides are 3 cm and 4 cm
3. To make a tasty jug of iced tea, you need 7 measuring scoops of iced tea powder for every litre (L) of water. How many scoops of iced tea powder will you need for: 2L,
4. Your parents are building a house that is 7m wide and 9 meters long. What will be the area of the house in m^2?
5. Dad has 2 baseball bats. How many baseball caps does he have if the total of baseball caps is one less than the triple number of baseball bats?
6. Bob is 2 years old and Don is 5 years old. How old is their mother if we know that her age is the sum of the squares of their ages?
7. Jo's age is the square root of his grandfather's age. How old is Jo if his grandfather is: 81, 100, 121 years old?
8. Multiply by 7m: 5m
9. Multiply by (-7m): 6x-6,
10. Divide by (-2x): 8x+6

Appendix B:
Researcher Designed Oral Mathematics Drill Activities

Oral Mathematics Drill Activity Set #1 Number Strand

1. What is the expanded form of: 1^2, 2^2, 5^2, 7^2, 8^2 9^2, 10^2, 11^2, 12^2, 15^2.
2. What is the square of: 1, 2, 5, 7, 8, 9, 10, 11, 12, 15.
3. What is the square root of: 1, 25, 36, 49, 64, 81, 100, 121, 144, 225.
4. Estimate the square root of: 3, 11, 17, 26, 37, 48, 65, 78, 95, 97.
5. Estimate the square root of: 34, 10, 24, 5, 50, 62, 80, 210, 98, 83.
6. What is 10 % of: 30, 50, 70, 80, 100, 120, 150, 200, 450, 900.
7. What is 20 % of: 30, 50, 70, 80, 100, 120, 150, 200, 450, 900.
8. What is 30 % of: 30, 50, 70, 80, 100, 120, 150, 200, 450, 900.
9. What is 5 % of: 30, 50, 70, 80, 100, 120, 150, 200, 450, 900.
10. To make a tasty jug of iced tea, you need 7 measuring scoops of iced tea powder for every litre (L) of water. How many scoops of iced tea powder will you need for: 2L, 3L, 4L, 5L, 8L, 10L, 12L, 15L, 20L, 25L of water?

Oral Mathematics Drill Activity Set #2 Number Strand

1. What is the square of: 10, 20, 7, 11, 15, 13, 9, 12.
2. What is the square root of: 169, 49, 100, 144, 225, 64, 16, 121.
3. Convert to decimals: 2/10, 3/4, 9/10, -4/5, 75/10, -12/5, 11/50, 15/20.
4. Convert to decimals: 10^{-2}, 10^{-1}: 3/4, -7/10, -48/10, -6/50, -9/5, 9/100.
5. Convert to fractions: 3.4, -0.1, -0.5, 2.4, -5.1, 0.62, 2.10, -9.8.
6. What is 10 % of: 30, 50, 70, 80, 100, 120, 150, 200, 450, 900.
7. What is 20 % of: 30, 50, 70, 80, 100, 120, 150, 200, 450, 900.
8. What is 30 % of: 30, 50, 70, 80, 100, 120, 150, 200, 450, 900.
9. What is 5 % of: 30, 50, 70, 80, 100, 120, 150, 200, 450, 900.
10 Express in fractional form: 10%, 18%, 25%, 40%, 60%, 81%, 95%, 150%

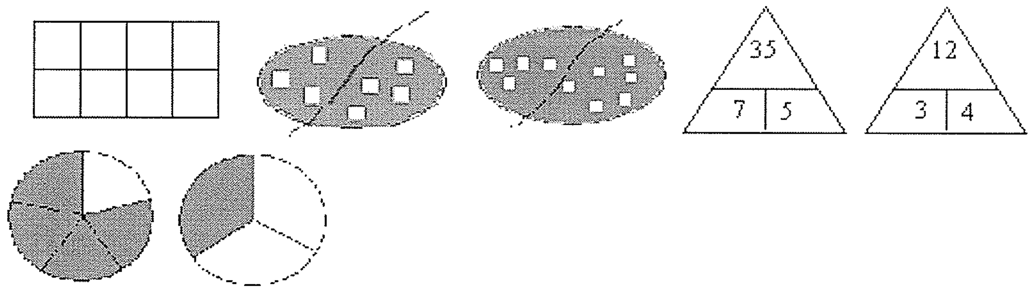
Oral Mathematics Drill Activity Set #3 Number Strand

1.	What is 1/2 of: 1/2, 2/3, 3/4, 3/5, 4/5, 5/6, 3/7, 5/9.
2.	What is 1/3 of: 1/2, 2/3, 3/4, 3/5, 4/5, 5/6, 3/7, 5/9.
3.	What is 2/3 of: 1/2, 2/3, 3/4, 3/5, 4/5, 5/6, 3/7, 5/9.
4.	What is 1/4 of: 1/2, 2/3, 3/4, 3/5, 4/5, 5/6, 3/7, 5/9.
5.	What is 3/4 of: 1/2, 2/3, 3/4, 3/5, 4/5, 5/6, 3/7, 5/9.
6.	Add 1/2 to: 1/2, 2/3, 3/4, 3/5, 4/5, 5/6, 3/7, 5/9
7.	Subtract 1/2 from: 1/2, 2/3, 3/4, 3/5, 4/5, 5/6, 3/7, 5/9
8.	Add 1/3 to: 1/2, 2/3, 3/4, 3/5, 4/5, 5/6, 3/7, 5/9
9.	Subtract 1/3 from: 1/2, 2/3, 3/4, 3/5, 4/5, 5/6, 3/7, 5/9
10.	How many 1/2 can you make from: 1/2, 2, 3, 3/4, 3/5, 4, 5/6, 7

Oral Mathematics Drill Activity #4 Patterns and Relations

1. Find the missing value in each ordered pair when y = 2x
   (1,_), (10,_), (100,_), (4,_), (40,_), (400,_), (7,_), (70,_)

2. State the corresponding equations



3. Create a table of values for the equation y = 5x

X	1	2	3	5	6	9	11	12
Y								

4. Create a table of values for the equation y = - 3x

X	1	2	3	4	5	6	7	8
Y								

5. What is one half of each of the following: 6, 60, 600, 6000, 60000

6. What is 5 added to each of the following: 8, 18, 28, 38, 58, 98, 108, 148

7. What is one more than the double of each of the following: 3, 5, 7, 9, 11, 13, 15

8. What is one less than the triple of each of the following: 2, 3, 5, 7, 10, 15, 20

9. State the number that is 3 more than half of each of the following:

   2, 5, 8, 10, 18, 25, 30

10. How many eggs are in: one, two five, seven, ten dozen?

Oral Mathematics Drill Activity Set #5 Patterns and Relations

1. How many are four of each: decade, century, millennium, pair, dozen

2. Continue the pattern

   2, 1/2, 3, 1/3, 4, 1/4,

3. Continue the pattern

   m+5, 3m+6, 6m+7, 10m+8,

4. Continue the pattern

X	1	2	4	8				
Y	5	20	35	50				

5 Continue the pattern

   m^2+1, m^3+2, m^5+3, m^8+4,

6. . What is one half of: 6, 6x, 6xy, 60, 60x, 60xy, 600, 600x, 600xy

7. What is 5 added to: 8, 8x, 28, 28xy, 58, 58m 98, 98my

8. What is one more than the double of: 3, 3t, 5, 7, 7t, 9, 9t, 13, 13t

9. What is one less than the triple of: 2, 2w, 3, 3w, 8, 8w, 11, 11w

10. State the number that is 3 more than half of each of:

   2, 2m, 5, $5m^2$, 8, $8z^3$, 10, 10mn, 25, $25mn^2$

Oral Mathematics Drill Activity Set #6 Patterns and Relations

1. How many are a quarter of each: decade, century, millennium, pair, dozen

2. Continue the pattern

-2, -1/2, +3, +1/3, -4, -1/4,

3. Continue the pattern

4m+15, 9m-16, 16m+17,

4. Continue the pattern

X	m	m^2	m^3	m^4				
Y	7	11	15	19				

5 Continue the pattern

m^4+1, m^3+2, m^2+3, m+4,

6. . What is one half of: 7, 7x, 7xy, 70, 70x, 70xy, 700, 700x, 700xy

7. What is 7 added to: 6, 6x, 56, 56m 98, 98my 216, 216xy,

8. What is one more than the double of: 8, 8t, 10, 10t, 14, 14t, 19, 19t

9. What is one less than the triple of: 4, 4w, 7, 7w, 13, 13w, 15, 15w

10. State the number that is 3 more than half of each of:

12, 12m, 50, $50m^2$, 82, $82z^3$, 86, 86mn, 90, $90mn^2$

Oral Mathematics Drill Activity Set #7 Patterns and Relations

1. How many is a half: decade, century, millennium, pair, dozen, minute
2. Subtract 5y from each: 2, 1/2y, 3y, 1/3xy, 4, 4y, 5y, 5my
3. Subtract 3z from each: 9z, 4m, 15, 11z, 16 z, 16mz,
4. Add 8h to each: 5yh, 7, 7h, 14yh, 14h, 25h, 5mh
5. Add 7c to each: c+1, m+2c, cm+3, 5c+2cm, a+4c, 3a+8c+4
6. Add 3m to half of each of: 12, 12m, 20, $20m^2$, 32, $32z^3$, 46, 46mn, 50, $50mn^2$
7. Multiply by 7m: 6, 6x, 6m, 5m, 8, 8my 9, 9m, 9xy,
8. Multiply by 3x half of: 4, 4t, 6, 6m, 8, 8x, 16, 16t
9. Divide by 3w: 3, 3w, 7, 7w, 12, $12w^2$, 15, $15w^2$
10. Divide by 5d: 3, 3d, 7, 7dw, 12, $12d^2$, 15, $15d^2$

Oral Mathematics Drill Activity Set #8 Patterns and Relations

1. Subtract (-5y) from: $5y-2$, $6y^2-3y$, 3^3-8z, $8xy-3$, $-4y^5-4$, $5my-5y$,
2. Subtract (-3y) from: $4y+2$, $-1/2y-4$, $2y^2+3y$, $1/3xy-y$, $-2mn+5y$, $5my-3y$
3. Add (-3z) to: $9z-6$, $-4m+2$, $2mz-15$, $-11z+5$, $16 z-11$, $-12mz-3z$
4. Add (-8h) to: $5yh+s$, $7m-2h$, $-7h-5$, $14yh-3h$, $-14h+2$, $-5h-25$
5. Multiply by (-7c): $c+1$, $m+2c$, $cm+3$, $5c+2cm$, $a+4c$, $3a+8c+4$
6. Multiply by (-3m): $2m+6$, $-2j+8$, $20m^2-x$, $-3z^3-7$, $-6mn+50$, $5mn^2-3$
7. Multiply by (-7m): $6x-6$, $6m^2-1$, $-5xm-2$, $8my+9$, $-3m-7$, $-9xy+7$
8. Divide by (-3x): 4, 4t, 6, 6m, 8, 8x, 16, 16t
9. Divide by (-4d): $3d+2$, $-4d+4$, $-7d^3-5$, $8dw-16d$, $-12d^{2+}20d$, $16d^5-40d$
10. Divide by (-3g): $3g-3$, $7g^3-7$, $-7gw-7g$, $12g^2-12g^2$, $-15g^4-9g$, $21mg^2-3g$

Oral Mathematics Drill Activity Set #9 Shape and Space

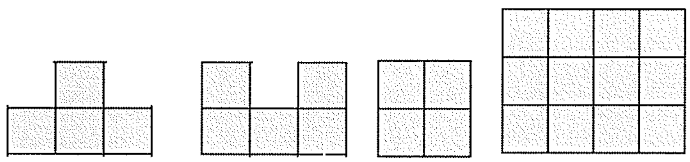
1. What is the total sum of the measure of the inside angles of a:

   triangle, square, rectangle, trapezoid?

2. What is the measure of the third angle in a right triangle if the second known angle is:

   10°, 20°, 30°, 48°, 56°, 69°, 72°

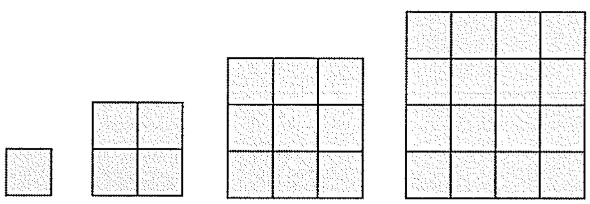
3. What is the perimeter of the following shapes:



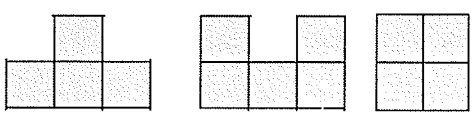
4. How much will the perimeter of a rectangle increase if each length and width increases by:

   1, 3, 4, 7, 8, 10, 11?

6. Determine the area of the following shapes if each small square represents a square unit.

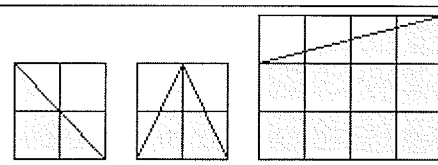


6 Determine the area of each of the following squares:



7. How many right angles does each 2D shape have: triangle, square, rectangle

8. Determine the area of the following shapes:



9. Determine the circumference of the circle if the radius is: 1, 2, 3, 4, 5, 6, 7 units long.

10. Determine the area of the circle (πr^2) if the radius is: 1, 2, 3, 4, 5, 6, 7 units long.

Oral Mathematics Drill Activity Set #10 Shape and Space

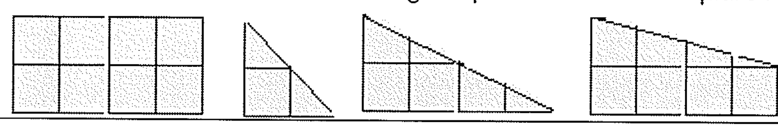
1. What is the measure of the third angle in a triangle if the other two angles are:

   100° and 35°, 20° and 90°, 35° and 80°, 48° and 60°, 56° and 74°, 69° and 40°

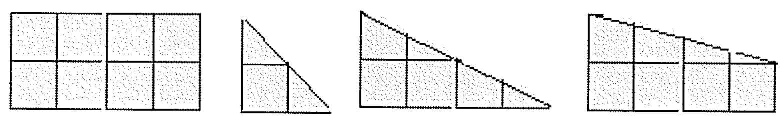
2. What is the length of the hypotenuse of the right triangle if the two sides are:

   3 cm and 4 cm, 3 units and 5 units, 12 m and 5 m, 12 km and 9 km, 7km and 4km

3. Determine the area of the following shapes if each small square represents a square unit.



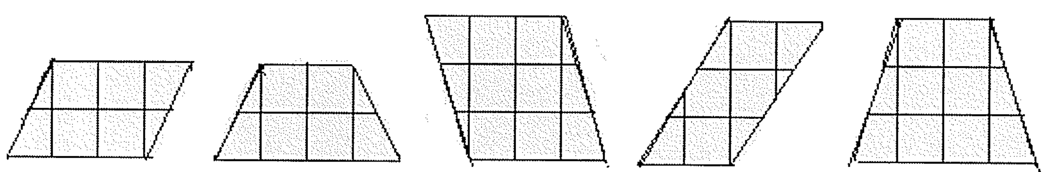
4. What is the perimeter of the following shapes:



5. Determine the area of a triangle if the height is 7 cm and the base is

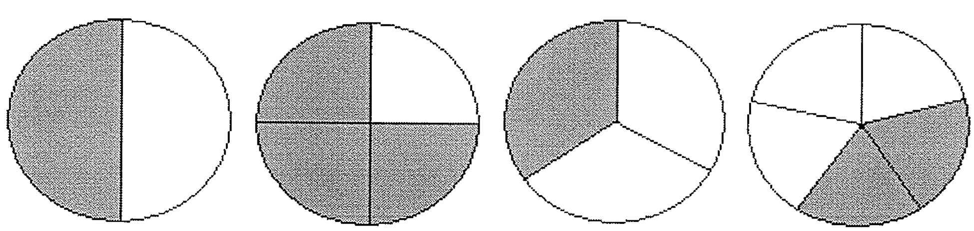
   3cm, 8cm, 9 cm, 10cm, 20cm, 100cm

6. Determine the area of each of the following shapes:



7. What would the area of each of the above shape be if the bases increased by7 units?

8. Determine the shaded area of each when the diameter is two units long.



:

9. Determine the circumference of the circle if the diameter is: 3, 5, 8, 12 units long.

10. Determine the area of the circle (πr^2) if the diameter is: 3, 5, 8, 12 units long.

Oral Mathematics Drill Activity Set #11 Statistics and Probability

1 .How could you express the following numbers out of a hundred? If you hear on the news that a certain political candidate has a

28%, 25%, 30% 50%, 60%, 75% 80% change of winning

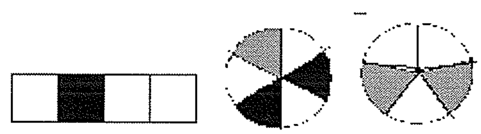
2. How would you express the same number in decimals?

3. Express as a fraction: 10%, 30%, 50%, 60%, 75%, 90%, 100%.

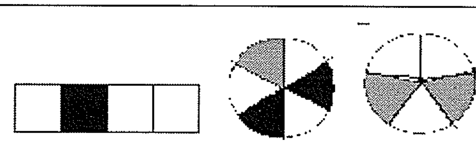
4. Express as a decimal: 15%, 20%, 25%, 42%, 68%, 79%, 81%.

5. Express as a decimal 10% of: 20, 35, 49, 53, 69, 78, 99.

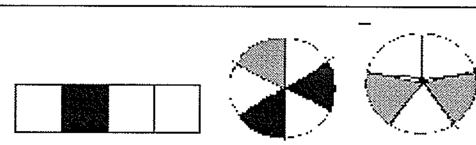
6. Express the shaded area as a percentage.



7. Express the shaded area as a fraction.



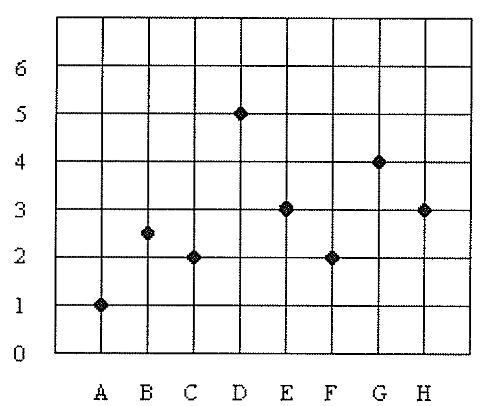
8. Express the shaded area as a decimal.



9 What is your chance of becoming the winner of a singing contest, if including you there are:

7, 12, 25, 60, 85, 200, 560 people entering?

10. What fraction of dots on this graph represents: more than 3, less than 3, 3?



Oral Mathematics Drill Activity Set #12 Statistics and Probability

1 Which measure of central tendency should you use to find the average of the following sets of data:
9, 8, 8, 5, 7, 8   2, 7, 8, 5, 3, 6   1, 8, 9, 7, 5   2, 8, 7, 6, 1   9, 7, 2, 5, 6

2. Find the average of each of the above sets of data using the appropriate measure of central tendency.

3. Find the average: 30%, 50%   60% 75%   90%, 100%.

4. Find the mean: 15%, 20%, 25%   42%, 38%, 60%   8%,12%, 7%.

5. Find the mean: 3, 5, 5, 9, 4,   6, 2, 3, 5, 4   7, 9, 3, 6, 5

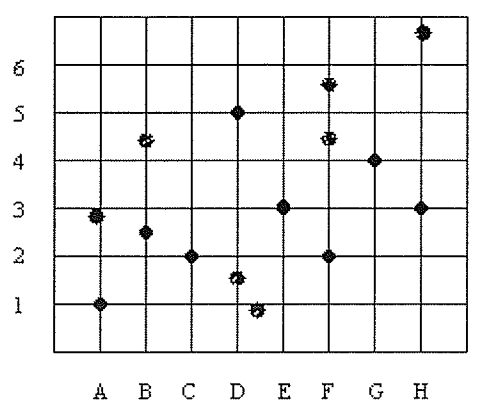
6. There were 4 yellow, 4 blue, 2 purple, 5 green and 3 red candies in the bag of candies you got for Easter. What is the probability of your first candy being:
green, purple, red, blue, yellow?

7 If your first candy was green, what is the probability of your second candy being:
green, purple, red, blue, yellow?

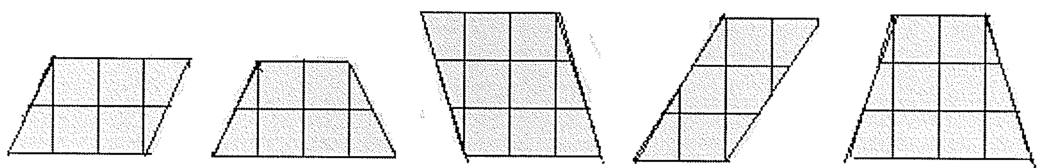
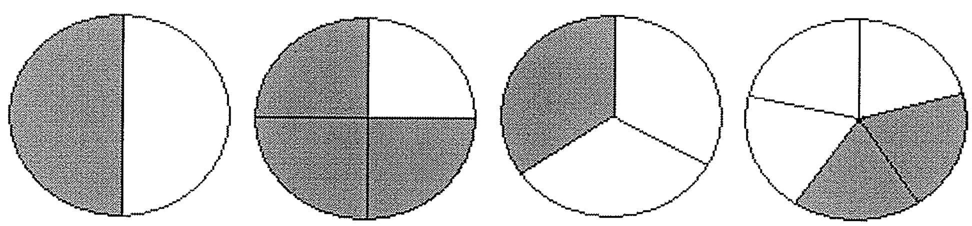
8. What is your chance of becoming the winner of a singing contest, if including you there are:
10, 12, 25, 38, 90, 235 people entering

9. State as a percent: 0.32, 0.89, 0.08, 0.98, 1.0

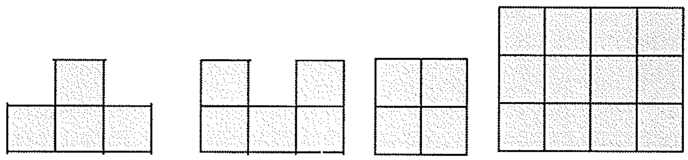
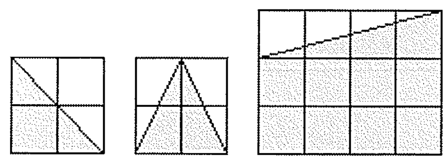
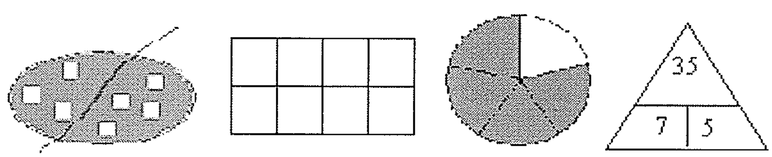
10. What fraction of dots on this graph represents: 4, more than 4, less than 4?



Oral Mathematics Drill Activity Set Word problems

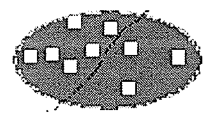
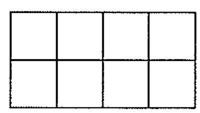
1. How many eggs are in: one dozen, five dozen, seven dozen, ten dozen?
2. What is your chance of becoming the winner of a singing contest, if including you there are: 60, 85, 200, 560 people entering?
3. Express the numbers out of a hundred. If you hear on the news that a certain political candidate has a 28%, 50%, 60%, 75%, 80% change of winning
4. What is 5 % of: 30, 50, 80, 100, 120, 200, 900.
5. What is the measure of the third angle in a triangle if the other two angles are: 20° and 90°, 35° and 80 °, 48° and 60°, 56° and 74°, 69° and 40°
6. What is the length of the hypotenuse of the right triangle if the two sides are: 3 cm and 4 cm, 3 units and 5 units, 12 m and 5 m, 12 km and 9 km
7. Determine the area of each of the following shapes: 
8. What would the area of each of the above shape be if the bases increased by 2 units?
9. Determine the area of the circle (πr^2) if the diameter is: 3, 5, 8, 12 units long.
10. Determine the shaded area of each when the diameter is two units long.  :
11. Determine the circumference of the circle if the diameter is: 3, 5, 8, 12 units long.
12. To make a tasty jug of iced tea, you need 7 measuring scoops of iced tea powder for every litre (L) of water. How many scoops of iced tea powder will you need for: 2L, 3L, 5L, 8L, 12L, 20L of water?

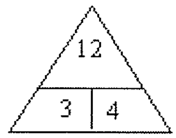
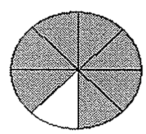
Oral Mathematics Drill Activity Set Word problems

13. How many are four of each: decade, century, millennium, pair, dozen
14. Your parents are building a house that is 7m wide and 9 meters long. What will be the area of the house in m^2?
15. Dad has 2 baseball bats. How many baseball caps does he have if the total of baseball caps is one less than the triple number of baseball bats?
16. Express in fractional form: 10%, 18%, 25%, 60%, 81%, 95%, 150%
17. Add 3m to half of each of: 12, 12m, 20, $20m^2$, 32, $32z^3$, $50mn^2$
18. What is the perimeter of the following shapes: 
19. Bob is 2 years old and Don is 5 years old. How old is their mother if we know that her age is the sum of the squares of their ages?
20. Jo's age is the square root of his grandfather's age. How old is Jo if his grandfather is: 81, 100, 121 years old?
21. Determine the area of the following shapes: 
22. Multiply by 7m: 6, 6x, 6m, 5m, 8, 8my 9, 9m, 9xy
23. Multiply by (-7m): 6x-6, $6m^2$-1, -5xm-2, 8my+9, -3m-7, -9xy+7
24. Divide by (-3x): 4, 4t, 6, 6m, 8, 8x, 16, 16t
25. Peter says his uncle is 3 years less than a half-century and his grandfather is 2 decades short of a century. What is the difference in their age in years?
26. State the corresponding equations 

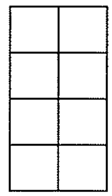
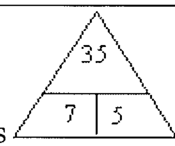
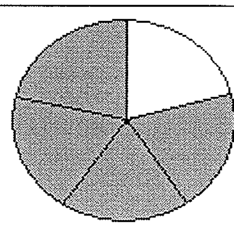
Appendix C:
Researcher Designed Tests

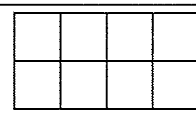
Researcher's Initial Mathematics Test

1. Solve Write the appropriate equations	
2. Solve	325 + 175 =
3. Add	(18) + (+5) =
4. Add	(-2) + (-9) =
5. State the appropriate equations	
6. How many is: one dozen?	
7. Add	(-32) + (+12) =
8. Subtract	(+25) – (+15) =
9. Subtract	(+43) – (-7) =
10. Subtract	(-81) –(+20)
11. Subtract	(-30)– (-8) =

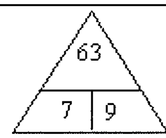
12. State the corresponding equations 
13. Multiply (+25) (+6) =
14. Multiply (+12) (-7) =
15. How many wheels are on 3 bikes?
16. Identify the fractions. 
17. Divide (350) / (-50) =
18. Divide (-280 / (+70) =
19. What is the degree measure of each angle in a square?
20. How many days are there in 6 weeks?
21. Tim has 8 kittens. He gave away 5 kittens last week and 3 kittens the week before last. How many kittens did he have originally?
22. How many uncles does Mona have, if her mother has 8 brothers and her father has 3 sisters?

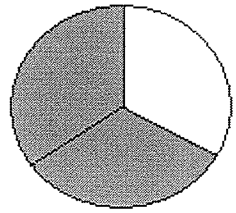
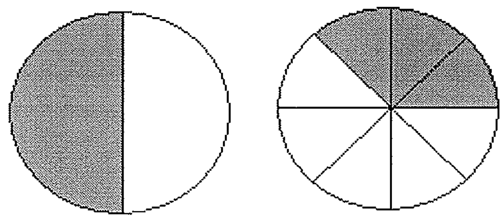
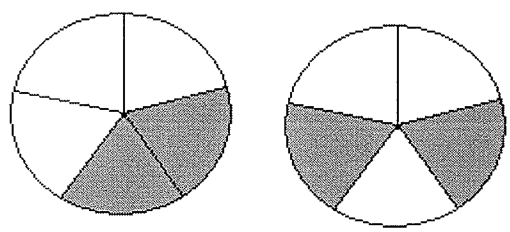
Researcher's Mid-way Mathematics Test

1. State the appropriate equations	
2. Add	$(-5) + (-7) =$
3. Subtract	$(-51) - (+20) =$
4. Multiply	$(-25)\ (+4) =$
5. Divide $(+450) / (+15) =$	
6. State the corresponding equations	
7. Add	$(+13x) + (-6x) =$
8. Subtract	$(+53x) - (-17x) =$
9. Multiply	$(-4x)\ (+3y) =$
10. Divide	$(12y^3) / (-4y) =$
11. Identify the fractions	

12. What is 25% of 400?
13. How many years in four decades?
14. How many years in 3/4 of a century?
15. What is the sum of half of 16 and a third of 9?
16. State the perimeter of this object 
17. Estimate (39) (51) =
18. Estimate 280 / 71 =
19. Estimate the square root of 84
20. How many $ will you need to add to $ 29 in order to buy a $ 45 jacket?
21. Tony has 4 hockey sticks. He gave away 2 hockey sticks last week and 3 hockey sticks the week before last. How many hockey sticks did he have originally?
22. How can Mimi figure out her uncle's age, if she knows that 2 years ago he was 34 years old?

Researcher's Final Mathematics Test

1.	Add 295 + 35 =
2.	Subtract 296 – 34 =
3.	Multiply (-25) (-5) =
4.	Divide (240) / (-60) =
5.	State the equations 
6.	How many wheels are on 5 cars?
7.	How much does each ticket cost if the total for 6 tickets is $ 30 ?
8.	Multiply by (-3m) the polynomial (2m-5y+9)
9.	Divide by (-2x) the polynomial (-2d+4x-10)
10.	There were 25 questions on the test. Walter got 80% of them correct. How many questions did he get correct?
11.	Tom's mother is 30 years old and his father is 34 years old. Tom's age is the square root of his mother's and his father's age combined. How old is Tom?

12.	 Identify the fractions.
13.	Peter had 12 hockey sticks. How many hockey sticks would you say Peter gave away, if he told you that he now has one third of the original amount?
14.	Mary's mother is 4 decades old. Mary is 2 years more than a quarter of her mother's age. How old is Mary?
15.	 Add (shaded area)
16.	 Subtract (shaded area)
17.	What is the perimeter of a 3m long and 5m wide room?
18.	How many eggs will your mother need if she wants to make three cakes and if each cake uses half-a-dozen eggs.
19.	What is your chance of winning a spelling contest if including you there are 32 students entering?
20.	There are 8 gift-baskets of apples, bananas and pears with the following label on each (5a + 3b + 4p). How many of each does the storekeeper need in order to fill all 8 baskets?
21.	What method of problem solving would you use? Why would you choose that particular method?
22.	How many square feet of carpet do you need in order to cover the floor if your room is 9 feet wide and 11 feet long?

Appendix D:
Researcher Designed Survey Questionnaires

Initial Student Survey Questionnaire

Please, complete each question in detail.

1. Do you find mathematics easy or difficult? Explain why.
2. What mathematical topics do you find easy?
3. What do you think makes those topics you named easy for you?
4. What mathematical topics do you find difficult?
5. What do you think makes those topics difficult?
6. When your teacher assigns math exercises to be done in class, how much of the work can you do on your own?
7. Describe the method(s) (strategy) you use to solve the math problems (exercises). These problems (exercises) can be word problems, geometry questions, algebra or simple arithmetic questions.
8. When you need help with your class work, what type of help do you need?
9. When you get homework in mathematics, what method(s) (strategy) do you use to complete each question? If you use a variety, state when you use each.
10. Why do you use that particular method of doing math exercises?
11. What portion of your homework do you usually manage to complete?
12. What portion of your completed homework is usually correct?
13. How much time does it usually take to do your math homework?
14. When you write a math test or quiz, do you usually manage to complete it? Why? Or Why not?
15. What portion of your math test or quiz is usually correct?
16. Do you prefer to work out your math problem in your head **or** by using a pen/pencil and a piece of paper **or** by using your calculator? Explain why?

Final Student Survey Questionnaire

Please, complete each question in detail.

1. Did you find the oral mathematics drills easy or difficult? Why?
2. Did you find the oral mathematics drills help improve your <u>accuracy</u> with simple operations? Why? Or Why not?
3. Did you find the oral mathematics drills help improve your <u>speed</u> while performing simple operations? Why? Or Why not?
4. Did the oral mathematics drills have any influence on your <u>class work</u>? How?
5. Did the oral mathematics drills have any influence on your <u>homework</u>? How?
6. Did the oral mathematics drills have any influence on how you solve questions on a math test or quiz? How?
7. When your teacher assigns math exercises to be done in class, how much of the work can you do on your own?

   Is that the same as you what you could do before you were expose to oral mathematics drills?
8. Describe the method (strategy) you use to solve the math problems (exercises) now.
9. When you need help with your class work, what type of help do you need?
10. When you get homework in mathematics, what method (strategy) do you use to complete each question?
11. Why do you use that particular method of doing math exercises?
12. What portion of your homework do you manage to complete?
13. What portion of your completed homework is usually correct?
14. How much time do you take to do your math homework?
15. When you write a math test or quiz, do you usually manage to complete it? Why? Or Why not?
16. What portion of your math test or quiz is usually correct?
17. Do you prefer to work out your math problem <u>in your head</u> or by <u>using a pen/pencil and a piece of paper</u> or by <u>using your calculator</u>? Explain why?

Appendix E:
Information Letters and Letters of Consent

Cover Letter for the School Board

To whom it may concern.

My name is Katarina Schilling. This year I am conducting a research study as part of my Master of Education program at the University of Manitoba, Faculty of Education. My subject of interest is Mathematics. The purpose of my research study is to explore the possible influence of oral mathematics on grade 9 students' mathematical learning. This means that I need to observe and work with a few grade-nine students after school.

With your permission, I would like to work with six to eight grade-nine students from your high school. As part of my research study, the grade-nine student participants will be exposed daily, for the duration of 3 months, to 5-10 minutes of oral mathematics drill activities and short quizzes. They will also be asked to do 2 surveys (one prior to exposure and one after exposure to oral mathematics) and 3 researcher designed, audio taped oral mathematics tests (one prior to exposure, one at the halfway point, and one after exposure to oral mathematics). All questions and drill activities are based on mathematics that students were exposed to in the previous grades. The total duration of involvement in this research study will be a little over three months.

With this letter attached is your letter of consent providing you with more information about this research project, as well as the letters addressed to the high-school principal, and the grade-nine students and their parents/guardians.
I am looking forward to your reply.

Sincerely,
Katarina Schilling

School Board Official's Letter of Consent

Research Project Title: Oral mathematics: How does it aid mathematics learning?

Researcher: Katarina Schilling – Telephone: [redacted] Email: [redacted]

Advisor Dr. Thomas Falkenberg - Telephone [redacted]
Email: [redacted]

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

Purpose of the Research: This research study is a master of education thesis project at the University of Manitoba. The purpose of my research study is to explore the possible influence of oral mathematics on grade 9 students' mathematical learning.

Procedures If you agree to permit 6 to 8 of your grade-nine students to participate in this research study, after school hours they will be (1) exposed to daily 5 to 10 minutes of oral mathematics activities for the period of three months, (2) given daily short quizzes prior to the oral mathematics activities, (2) asked to fill in two survey questionnaires about 30–45 minutes each (one prior to and one at the end of the three month exposure to oral mathematics), and (3) asked to participate in three 30-45 minute researcher designed, audio taped oral mathematics tests (one prior to exposure, one at the halfway point, and one after exposure to oral mathematics).

Recording and Transcription: With permission, the three oral mathematics test sessions will be audio-recorded. The researcher will take notes during the session. The recording of the session will be transcribed for the purpose of analysis.

Associated Risks and Benefits: The benefits of this research for educators will be to gain some understanding of the possible influence of oral mathematics on grade nine students toward mathematics. The benefits of this research study to the students are that they are provided with consistency i.e. daily oral mathematical activities, they practice quick mental activities, they practice relying less on their calculator and more on their brain, and they are provided with instant confirmation to the correctness of their response. The risk of potential harm with participation is no greater than that which one might experience in the normal conduct of one's everyday life.

Confidentiality: To protect confidentiality pseudonyms will be used in the analysis and reporting of the study. The participants' name and the name of the school will not appear on the oral test session transcripts or the notes taken during the sessions. Only I, the researcher will know the real identity of the subjects. I, will conduct all the interviews and will be the only one doing all the transcribing in the privacy of my home; I will make sure that no one else will have access to the recordings and I will be alone in the room while listening to the recordings. I will store the data only on the home computer and the files are password protected; all tapes and printout material I will keep in a locked filing cabinet at my home where I only have access to the filing cabinet. Data will be destroyed upon the completion of the research project and requirements of the master's program.

Feedback The final results of this research project will be made available upon your request. If you wish to obtain a copy of this study please write your mailing and/or email address in the space provided at the bottom of this consent form and I will be happy to send you a copy <u>after</u> the completion of the research study and the requirements of the master's program.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and/or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

The researcher, Katarina Schilling, can be contacted at [redacted], her advisor Dr. Thomas Falkenberg at [redacted]

This research has been approved by the Education and Nursing Research and Ethics Board.
If you have any concerns or complaints about this project you may contact any of the above-named persons or Zana Lutfiyya, Acting Associate Dean (Graduate Programs and Research) at [redacted] or [redacted]. A copy of this consent form has been given to you to keep for your records and reference.

Date)____

____

School Board Official's
Signature)____

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Mailing address and/or email address if you wish to receive a summary of the results.

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Cover Letter for the School Principal

To whom it may concern.

My name is Katarina Schilling. This year I am conducting a research study as part of my Master of Education program at the University of Manitoba, Faculty of Education. My subject of interest is Mathematics. The purpose of my research study is to explore the possible influence of oral mathematics on grade 9 students' mathematical learning. This means that I need to observe and work with a few grade-nine students after school.

With your permission, I would like to work in your school after classes with six to eight of your grade-nine students. There would be no teacher involvement necessary since the entire research study is intended to take place outside of the regular classes, after school hours. I would, though, need the help of your school secretary to send out letters to grade 9 students and their parents/guardians; and as well providing us (the student participants and myself) with a room to work in.
As part of my research study, the grade-nine student participants will be exposed daily, for the duration of 3 months, to 5-10 minutes of oral mathematics drill activities and short quizzes. They will also be asked to do 2 surveys (one prior to exposure and one after exposure to oral mathematics) and 3 researcher-designed, audio taped oral mathematics tests (one prior to exposure, one at the halfway point, and one after exposure to oral mathematics). All questions and drill activities are based on mathematics that students were exposed to in the previous grades. The total duration of involvement in this research study will be a little over three months.

If permission is granted by yourself, and the school board officials, the research study will be conducted in the following order: 1. I will ask that your school secretary forward the cover letter and the letter of consent addressed to the, grade-nine student and parent/guardian, to ask for their participation in this research study. If they choose to participate, they will need to return a signed letter of consent. 2. Student participants, who send in a signed letter of consent, will be asked to meet with me for the first time for about 30-45 minutes and will be given a survey questionnaire to fill out. 3. Individual audio taped 30–45 minute oral mathematics test will be scheduled and conducted. 4. The whole group of student participants will be meeting with me after school each day for about 10-15 minute for 3 months. During the daily sessions each student will be given a short quiz (to keep track of daily progress), an explanation of the activity of the day and 5-10 minutes of oral mathematics drill activities. 4. At the halfway point, close to two months into the research study, a second set of individual audio taped 30–45 minute oral mathematics test will be scheduled and conducted. 5. After the three-month exposure to oral mathematics activities a third (final) individual audio taped 30–45 minute oral mathematics test will be scheduled and conducted. 6. A final group meeting with all the participants for about 30-45 minutes will take place, during which a final survey questionnaire will be given to each participant to fill out. At the end of the final meeting I will thank the participants for all their effort they put into this research study.

With this letter attached is your letter of consent providing you with more information about this research project.
I am looking forward to your reply.

Sincerely,
Katarina Schilling

Principal's Letter of Consent

Research Project Title:
Oral mathematics: How does it aid mathematics learning?

Researcher: Katarina Schilling – Telephone: [redacted] Email [redacted]

Advisor: Dr. Thomas Falkenberg - Telephone [redacted]
Email:[redacted]

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

Purpose of the Research: This research study is a master of education thesis project at the University of Manitoba. The purpose of my research study is to explore the possible influence of oral mathematics on grade 9 students' mathematical learning.

Procedures: If you agree to permit 6 to 8 of your grade-nine students to participate in this research study, after school hours they will be (1) exposed to daily 5 to 10 minutes of oral mathematics activities for the period of three months, (2) given daily short quizzes prior to the oral mathematics activities, (2) asked to fill in two survey questionnaires about 30–45 minutes each (one prior to and one at the end of the three month exposure to oral mathematics), and (3) asked to participate in three 30-45 minute researcher designed, audio taped oral mathematics tests (one prior to exposure, one at the halfway point, and one after exposure to oral mathematics).

Recording and Transcription: With permission, the three oral mathematics test sessions will be audio-recorded. I, the researcher, will take notes during the session. The recording of the session will be transcribed for the purpose of analysis.

Associated Risks and Benefits: The benefits of this research for educators will be to gain some understanding of the possible influence of oral mathematics on grade nine students toward mathematics. The benefits of this research study to the students are that they are provided with consistency i.e. daily oral mathematical activities, they practice quick mental activities, they practice relying less on their calculator and more on their brain, and they are provided with instant confirmation to the correctness of their response. The risk of potential harm with participation is no greater than that which one might experience in the normal conduct of one's everyday life.

Confidentiality: To protect confidentiality pseudonyms will be used in the analysis and reporting of the study. The participants' name and the name of the school will not appear on the oral test session transcripts or the notes taken during the sessions. Only I, the researcher will know the real identity of the subjects. I, will conduct all the interviews and will be the only one doing all the transcribing in the privacy of my home; I will make sure that no one else will have access to the recordings and I will be alone in the room while listening to the recordings. I will store the data only on the home computer and the files are password protected; all tapes and printout material I will keep in a locked filing cabinet at my home where I only have access to the filing cabinet. Data will be destroyed upon the completion of the research project and requirements of the master's program.

Feedback: The final results of this research project will be made available upon your request. If you wish to obtain a copy of this study please write your mailing and/or email address in the space provided at the bottom of this consent form and I will be happy to send you a copy after the completion of the research study and the requirements of the master's program.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and/or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

The researcher, Katarina Schilling, can be contacted at [redacted], her advisor Dr. Thomas Falkenberg at [redacted]
This research has been approved by the Education and Nursing Research and Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-named persons or Zana Lutfiyya, Acting Associate Dean (Graduate Programs and Research) at [redacted] or [redacted]. A copy of this consent form has been given to you to keep for your records and reference.

Date____

Principal's Signature)______________________________________

Mailing address and/or email address if you wish to receive a summary of the results.

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Cover Letter for the Parent/ Guardian

To whom it may concern.

My name is Katarina Schilling. This year I am conducting a research study as part of my Master of Education program at the University of Manitoba, Faculty of Education. My subject of interest is Mathematics. The purpose of my research study is to explore the possible influence of oral mathematics on grade 9 students' mathematical learning. This means that I need to observe and work with a few grade-nine students after school.

The student benefits of this research study are that students are provided with a lot of extra time in mathematics; very much like tutoring but without the financial burden to the parents. Students will be experiencing consistency i.e. daily exposure to oral mathematics activities, quick mental activities, practice relying less on their calculator, and they will be provided with instant confirmation to the correctness of their response. By daily exposure to oral mathematics activities subjects practice mathematical problem solving quickly, accurately, and efficiently

As part of my research study, the grade-nine student participants will be exposed daily, for the duration of 3 months, to 5-10 minutes of oral mathematics drill activities and short quizzes. They will also be asked to do 2 surveys (one prior to exposure and one after exposure to oral mathematics) and 3 researcher designed, audio taped oral mathematics tests (one prior to exposure, one at the halfway point, and one after exposure to oral mathematics). All questions and drill activities are based on mathematics that students were exposed to in the previous grades. The total duration of involvement in this research study will be a little over three months.

The research study will be conducted in the following order: 1. I am forwarding this letter and a letter of consent to you, parent/guardian of a grade-nine student, to ask you for your approval of your grade nine student's participation in this research study; as well, I am forwarding a similar letter and a letter of assent to your grade-nine student to ask him/her for his/her participation in this research study. If you choose to let your grade nine student participate, please, return your signed letter of consent along with his/her signed letter of assent. 2. Student participants, who send in a signed letter of assent along with a signed letter of consent from their parent/guardian, will be asked to meet with me for the first time for about 30-45 minutes and will be given a survey questionnaire to fill out. 3. Individual audio taped 30-45 minute researcher-designed oral mathematic tests will be scheduled and conducted. 4. The whole group of student participants will be meeting with me after school each day for about 10-15 minute for 3 months. During the daily sessions each student will be given a short quiz (to keep track of daily progress), an explanation of the activity of the day and 5–10 minutes of oral mathematics drill activities. 4. At the halfway point, close to two months into the research study, a second set of individual audio taped 30–45 minute oral mathematics tests will be scheduled and conducted. 5. After the three-month exposure to oral mathematics activities a third (final) individual audio taped 30–45 minute oral mathematic test will be scheduled and conducted. 6. A final group meeting with all the participants for about 30-45 minutes will take place, during which a final survey questionnaire will be given to each participant to fill out. At the end of the final meeting I will thank the participants for all their effort they put into this research study.

With this letter attached is your letter of consent providing you with more information about this research project.
I am looking forward to your reply.

Sincerely,
Katarina Schilling

Parent/Guardian's Letter of Consent

Research Project Title: Oral mathematics: How does it aid mathematics learning?

Researcher: Katarina Schilling – Telephone: [redacted] Email: [redacted]

Advisor: Dr. Thomas Falkenberg - Telephone [redacted]
Email: [redacted]

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

Purpose of the Research: This research study is a master of education thesis project at the University of Manitoba. The purpose of my research study is to explore the possible influence of oral mathematics on grade 9 students' mathematical learning.

Procedures: If you agree to let your grade 9 student participate in this research study, after school hours he/she will be (1) exposed to daily to 5 to 10 minutes of oral mathematics activities for the period of three months, (2) given daily short quizzes prior to the oral mathematics activities, (2) asked to fill in two survey questionnaires about 30-45 minutes each (one prior to and one at the end of the three month exposure to oral mathematics), and (3) asked to participate in three 30-45 minute researcher designed, audio taped oral mathematics tests (one prior to exposure, one at the halfway point, and one after exposure to oral mathematics).

Recording and Transcription: With permission, the three oral test sessions will be audio-recorded. The researcher will take notes during the session. The recording of the session will be transcribed for the purpose of analysis.

Associated Risks and Benefits: The benefits of this research for educators will be to gain some understanding of the possible influence of oral mathematics on grade nine students toward mathematics. The benefits of this research study to the students are that they are provided with consistency i.e. daily oral mathematical activities, they practice quick mental activities, they practice relying less on their calculator and more on their brain, and they are provided with instant confirmation to the correctness of their response. The risk of potential harm with participation is no greater than that which one might experience in the normal conduct of one's everyday life.

Confidentiality: To protect confidentiality pseudonyms will be used in the analysis and reporting of the study. The participants' name and the name of the school will not appear on the oral test session transcripts or the notes taken during the sessions. Only I, the researcher will know the real identity of the subjects. I, will conduct all the interviews and will be the only one doing all the transcribing in the privacy of my home; I will make sure that no one else will have access to the recordings and I will be alone in the room while listening to the recordings. I will store the data only on the home computer and the files are password protected; all tapes and printout material I will keep in a locked filing cabinet at my home where I only have access to the filing cabinet. Data will be destroyed upon the completion of the research project and requirements of the master's program.

Feedback: The final results of this research project will be made available upon your request. If you wish to obtain a copy of this study please write your mailing and/or email address in the space provided at the bottom of this consent form and I will be happy to send you a copy after the completion of the research study and the requirements of the master's program.

Your signature on this form indicates that you have understood to your satisfaction the information regarding your grade 9 student's participation in the research project and agree to let him/her participate in this research study. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. Your grade 9 student is free to withdraw from the study at any time, and /or refrain from answering any questions he/she prefers to omit, without prejudice or consequence. If your grade 9 student withdraws, the data collected from him/her will not be reported. Your grade 9 student's continued participation should be as informed as his/her initial consent, so he/she and you should feel free to ask for clarification or new information throughout his/her participation.

The researcher, Katarina Schilling, can be contacted at [redacted], her advisor Dr. Thomas Falkenberg at [redacted]
This research has been approved by the Education and Nursing Research and Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-named persons or Zana Lutfiyya, Acting Associate Dean (Graduate Programs

and Research) at [redacted] or [redacted]. A copy of this consent form has been given to you to keep for your records and reference.

Date____

Name of the student (please print)

____

Signature
(parent/guardian)____

____

Mailing address and/or email address if you wish to receive a summary of the results.

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Cover Letter for the Student Participants

To whom it may concern.

My name is Katarina Schilling. This year I am conducting a research study as part of my Master of Education program at the University of Manitoba, Faculty of Education. My subject of interest is Mathematics. The purpose of my research study is to explore the possible influence of oral mathematics on grade 9 students' mathematical learning. This means that I need to observe and work with a few grade-nine students after school.

The student benefits of this research study are that students are provided with a lot of extra time in mathematics; very much like tutoring (but in a small group-setting). You will be experiencing consistency i.e. daily exposure to oral mathematical activities, quick mental activities, practice relying less on your calculator, and you will be provided with instant confirmation to the correctness of your response. By daily exposure to oral mathematics activities you will practice mathematical problem solving quickly, accurately, and efficiently.

As part of my research study, you, the grade-nine student participants will be exposed daily, for the duration of 3 months, to 5-10 minutes of oral mathematics drill activities and short quizzes. You will also be asked to do 2 surveys (one before exposure and one after exposure to oral mathematics) and 3 researcher-designed, audio-taped oral mathematics tests (one before exposure, one at the halfway point, and one after exposure to oral mathematics). All questions and drill activities are based on mathematics that you were exposed to in the previous grades. The total duration of involvement in this research study will be a little over three months.

The research study will be conducted in the following order: 1. I am forwarding this letter and a letter of assent to you, grade-nine student to ask for your participation in this research study; and a similar letter and a letter of consent to your parents/guardians, to ask them for their approval of your participation in this research study. If you choose to participate, please, return your signed letter of assent to the school secretary. 2. Student participants, who send in a signed letter of consent, will be asked to meet with me for the first time for about 30-45 minutes and will be given a survey questionnaire to fill out. 3. Individual audio taped 30–45 minute researcher-designed oral mathematics tests will be scheduled and conducted. 4. The whole group of student participants will be meeting with me after school each day for about 10-15 minute for 3 months. During the daily sessions each student will be given a short quiz (to keep track of daily progress), an explanation of the activity of the day and 5–10 minutes of oral mathematics drill activities. 4. At the halfway point, close to two months into the research study, a second set of individual audio taped 30–45 minute oral mathematics tests will be scheduled and conducted. 5. After the three-month exposure to oral mathematics activities a third (final) individual audio taped 30–45 minute oral mathematics test will be scheduled and conducted. 6. A final group meeting with all the participants for about 30-45 minutes will take place, during which a final survey questionnaire will be given to each participant to fill out. At the end of the final meeting I will thank the participants for all their effort they put into this research study.

With this letter attached is your letter of assent providing you with more information about this research project.
I am looking forward to your reply.

Sincerely,
Katarina Schilling

Student's Letter of Consent

Research Project Title: Oral mathematics: How does it aid mathematics learning?

Researcher: Katarina Schilling – Telephone: [redacted] Email: [redacted]

Advisor: Dr. Thomas Falkenberg - Telephone [redacted]
Email:[redacted]

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

Purpose of the Research: This research study is a master of education thesis project at the University of Manitoba. The purpose of my research study is to explore the possible influence of oral mathematics on grade 9 students' mathematical learning.

Procedures: If you agree to participate in this research study, after school hours you will be (1) exposed to daily to 5 to 10 minutes of oral mathematics activities for the period of three months, (2) given daily short quizzes prior to the oral mathematics activities, (2) asked to fill in two survey questionnaires about 30 –45 minutes each (one before and one at the end of the three month exposure to oral mathematics), and (3) asked to participate in three 30-45 minute researcher designed, audio taped oral mathematics tests (one before exposure, one at the halfway point, and one after exposure to oral mathematics).

Recording and Transcription: With permission, the three oral test sessions will be audio-recorded. I will take notes during the session. The recording of the session will be transcribed for the purpose of analysis.

Associated Risks and Benefits: The benefits of this research for educators will be to gain some understanding of the possible influence of oral mathematics on grade nine students toward mathematics. The benefits of this research study to you students are that you are provided with consistency i.e. daily oral mathematical activities, you practice quick mental activities, you practice relying less on your calculator and more on your brain, and you are provided with instant confirmation to the correctness of your response. The risk of potential harm with participation is no greater than that which one might experience in the normal conduct of one's everyday life.

Confidentiality: To protect confidentiality pseudonyms (fake names) will be used in the analysis and reporting of the study. Your name and the name of your school will not be on the oral test session transcripts or the notes taken during the sessions. Only I, the researcher, will know the real identity of those who participated in my research study. I, will be asking all the interview questions myself and will be the only one doing all the transcribing in the privacy of my home; I will make sure that no one else will have access to the recordings and I will be alone in the room while listening to the recordings. I will store the data only on the home computer and the files are password protected; all tapes and printout material I will keep in a locked filing cabinet at my home where I only have access to the filing cabinet. Data will be destroyed once I complete the research project and requirements of the master's program.

Feedback: The final results of this research project will be made available upon your request. If you wish to obtain a copy of this study please write your mailing and/or email address in the space provided at the bottom of this assent form and I will be happy to send you a copy after I complete the research study and the requirements of the master's program.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. If you withdraw, the data (the answers you give) will not be reported (will no longer serve as part of the research). Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

The researcher, Katarina Schilling, can be contacted at [redacted], her advisor Dr. Thomas Falkenberg at [redacted]
This research has been approved by the Education and Nursing Research and Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-named persons or Zana Lutfiyya, Acting Associate Dean (Graduate Programs and Research) at [redacted] or [redacted]. A copy of this consent form has been given to you to keep for your records and reference.

Date____

Name of the grade 9 student (please print)

____

Signature (of the grade 9 student)

____

____

Mailing address and/or email address if you wish to receive a summary of the results.

Appendix F:
Quiz Date- and Timeline

Month	Feb							
Date	11	12	13	17	18	19	20	23
Strand	Num	ber						
Activity	# 1		# 2		# 3			
Quiz #	1	2	3	4	5	6	7	8

Month	Feb				Mar				
Date	24	25	26	27	2	3	4	5	6
Strand	Patt	ems	&	Rela	tions				
Activity		# 4			# 5			# 6	
Quiz #	9	10	11	12	13	14	15	16	17

Month	Mar									
Date	9	10	11	12	13	16	17	18	19	20
Strand	Patt	ems	&	Rela	tions					
Activity			# 7					# 8		
Quiz #	18	19	20	21	22	23	24	25	26	27

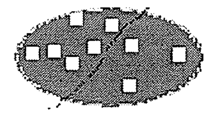
Month	Mar					April
Date	23	24	25	26	27	6
Strand	Shape	&	Space			
Activity			#9			
Quiz #	28	29	30	31	32	33

Month	April							
Date	6	7	8	9	14	15	16	17
Strand	Shape	&	Space					
Activity				# 10				
Quiz #	34	35	36	37	38	39	40	41

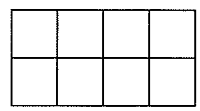
Month	April									May	
Date	20	21	22	23	24	27	28	29	30	1	4
Strand		S t a	t I s	t I c s	&	P r o b	a b	I I	I t y		
Activity			#11					#12			prob
Quiz #	42	43	44	45	46	47	48	49	50	51	solv

Appendix G:
Test Transcripts and Test Codes

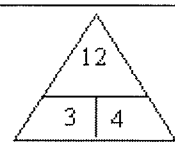
Researcher's Initial Mathematics Test



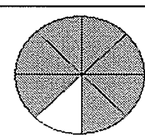
1. Solve Write the appropriate equations
2. Solve 325 + 175 =
3. Add (18) + (+5) =
4. Add (-2) + (-9) =



5. State the appropriate equations
6. How many is: one dozen?
7. Add (-32) + (+12) =
8. Subtract (+25) – (+15) =
9. Subtract (+43) – (-7) =
10. Subtract (-81) –(+20)
11. Subtract (-30)– (-8) =



12. State the corresponding equations
13. Multiply (+25) (+6) =
14. Multiply (+12) (-7) =
15. How many wheels are on 3 bikes?



16. Identify the fractions.
17. Divide (350) / (-50) =
18. Divide (-280 / (+70) =
19. What is the degree measure of each angle in a square?
20. How many days are there in 6 weeks?
21. Tim has 8 kittens. He gave away 5 kittens last week and 3 kittens the week before last. How many kittens did he have originally?
22. How many uncles does Mona have, if her mother has 8 brothers and her father has 3 sisters?

Time (minutes: seconds) and Student Response for

Student #1

Question # & code	Time	Student Response
1. P	0:10	"6 divided by 3 or as a fraction it's 6 over 3 and it's an improper fraction," (Me: Anything else?) "No. Could be 3 divided by 6 or decimal; decimal 6, decimal3."
2. N	0:02	"500"
3. N	0:01	"23"
4. N	0:01	"Negative 11"
5. P	0:19	"Hmm, it could be fractions again. May be whole fractions or two, four six, eight out of eight." (Me: Anything else?) "I suppose you could do 2 times 4 equals 8" (Me: Anything else?) "No."
6. W	0:02	"One dozen? Twelve"
7. N	0:01	"Negative 20"
8. N	0:01	"10"
9. N	0:06	"43 minus 7, 40 minus 4; thirty six"
10. N	0:03	"Negative one hundred two"
11. N	0:13	"Negative 38, wait that's negative 22 I think, because you are subtracting the negative. Yah, that would be negative 22."
12. P	0:40	"I have no clue what that means. Let's see. There is a twelve. I suppose it represents how much space it takes up. May be the area value 12 cm squared, 3 cm squared, 4 cm squared. I can't tell you." (Me: The combination of the three numbers don't mean much to you?) "I suppose, you could add them, which would equal 19." (Me: Anything else?) You could add 3 and 4 or try to divide or something of that sort. I'm not sure with this equation."
13. N	0:05	"Hundred twenty five. Wait, no, hundred fifty."
14. N	0:04	"Negative 84."
15. W	0:06	"What type of bikes? Motorcycles or just normal bikes?" (Me: Regular bikes.) "Six"
16. N	0:06	"Let's see here; 5 sixths or 1 sixth."
17. N	0:07	35 divided by 5 equals 7 and so it's 70."
18. N	0:12	"28 divided by 7 (counting quietly and extremely fast) 7, 14, 21, 28 so 40 or was there a negative in there?" (Me: negative 280 divided by positive 70.) "Negative 40."
19. W	0:10	"Degree measure? In a square? 90 degrees? I'm not sure."
20. W	0:09	"24 times 6, 25 times 6 equals 150 minus 6, 166?"
21. W	0:10	"Originally he had 11, I think. The eight he gave away last week and the three the week before, that makes 11."
22. W	0:08	"8. All right, it depends if the sisters are married. So, 11 if the sisters are married."

Student #2

Question #& code	Time	Student Response
1. P	0:10	"Uh, 6 over 3" (Me: Anything else?) "Oh, 6 divided by 3 equals 2." (Me: Anything else?) "No"
2. N	0:11	"Can I see? Uh, (pause) uh, (pause) 410."
3. N	0:09	"Uh 18 plus positive 5, uh 23."
4. N	0:02	"Negative 11."
5. P	0:13	"Umm 8." (Me: Anything that those squares make you think of?) "8 squares" Me: What kind of equations, though? Any equations?) "No"
6. W	0:01	"12"
7. N	0:03	"Uh negative 20"
8. N	0:02	"15, umm 10."
9. N	0:03	'Uh 50"
10. N	0:03	"Negative 101"
11. N	0:02	"Negative 38"
12. P	0:15	"3 and umm 3 times 4 equals 12, uh, 12 divided by 3 equals 4, or 12 divided by 4 equals 3." (Me: Anything else?) "No"
13. N	0:43	"Times? Uh 50? Can I see, uh, Can I write it down? I am not good at mental math." (Me: Sure. I'll give you a piece of paper and a pen) "Uh 150"
14. N	0:09	"Uh" (Writing it down) "Negative 84."
15. W	0:03	"3bikes, uh 6."
16. P	0:07	"Umm, 7 over 8 (Me: Anything else?) "No."
17. N	0:07	(Pause. Student writing down the question.) "Umm 7, (Emphasizes) 7."
18. N	0:02	"4"
19. W	0:09	"I don't know what that is. (Me: How many degrees do you have in each angle in a square?) "Uh, 90 degrees."
20. W	0:05	"Uh 42"
21. W	0:03	"Uh 16"
22. W	0:33	"Uh 3 uncles and 3 aunts. Can you repeat the question? Uh O.K. Uh 8. 8 uncles" (Me: Reason?) "Her mother has 8 brothers."

Student #3

Question # & code	Time	Student Response
1. P	0:24	"All right. Oh. It has 9 squares. It is an oval and it has a line going diagonally in the middle of the oval." (Me: What mathematical statements come across?) "Uh, diameter and surface area." (Me: Equations) "None."
2. N	0:12	(Student quietly whispering.) "325 + 175 ah Can I see the question, please?" (Again whispering.) "325 so 300, 30, 400" Stating aloud) "500"
3. N	0:03	"18 ah 20, (then accenting) 23"
4. N	0:01	"Negative 11"
5. P	0:18	"Ah, nothing; none." (Me: Think of something. What do you see there?) "A whole one." (Me: O.K. What else do you see there?) "8 squares, 8 over 8 equals 1 over 1" (Me: Anything else?) "No."
6. W	0:02	"One dozen is 12."
7. N	0:03	"Negative 30 ah (then accenting) 23, (even louder) negative 20."
8. N	0:02	"Ah 10"
9. N	0:03	"Ah 50, no, yah 50."
10. N	0:05	"Ah, negative hundred one."
11. N	0:04	"O.K. negative 22."
12. P	0:08	"Ah, 3 times 4 equals 12, 12 divided by 3 equals 4, 12 divided by 4 equals 3, and yah."
13. N	0:01	"Hundred fifty."
14. N	0:11	"56, (pause) 56, 68, 70, what ah, Can I see the question?" "Negative 70."
15. W	0:01	"Ah, 6."
16. P	0:11	"One seventh, or one eighth, ah, 7 over 1."
17. N	0:08	"Ah 300,350, 400, 450 ah (Counting very quietly, then saying loud) seven.
18. N	0:08	"I don't know." (Me: Would you like to see it?) "Oh 70, negative 40 no, negative 4."
19. W	0:11	(Quietly) "Ah, What is the degree measure of each angle in a square? They are all the same?" (Me: How many degrees are the each?) "Ah, 90."
20. W	0:03	"6 weeks, 6 times 7 is 42"
21. W	0:09	"Ah, he has 8, 8+5 equals 13, sixteen"
22. W	0:25	"3 and O.K. 8and 3, eleven uncles." (Me: How do you figure that. Give me the reason.) "O.K. because, her aunties might have married3 and then her mom has 8 brothers and that's 11."

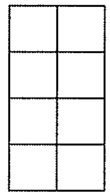
Student #4

Question # & code	Time	Student Response
1. P	0:24	"6 divided by 3, 2 over 1, in fraction form because 6:3 is 2."
2. N	0:25	"Um. Can I use a piece of paper please? Oh, 400, no, 500."
3. N	0:03	"18 plus positive 5, twenty three"
4. N	0:02	"Um negative 14"
5. P	1:02	"Oh, so there are 8 squares and I think that would be about it. If you want to look into fraction form, if you shade in one square it would be 1 over 8. Addition, maybe 4 plus 4 would equal 8, so you add 4 cubes and 4 cubes come to another 8. Subtraction, because, say take away 3 from 8 would be 5. Division, because what is 8 divided by 2; that would be 4 and multiplication, 4 times 2 would be 8."
6. W	0:01	"Uh 12"
7. N	0:06	"Uh, negative 32 plus positive 12, uh negative 20."
8. N	0:02	"Uh, 10."
9. N	0:08	"Oh, uh, 40 oh, uh 50."
10. N	0:16	"59, no, no, positive 20? It would be negative 61."
11. N	0:09	"Oh, uh, negative, no, 22, yah."
12. P	1:08	"To me, it kind of reminds me of something I do. Something in science. Like finding the density of an object, like density for unit... So, something like what we call the Devin circle. So density, no, mass would be on the top, density and volume would be on the bottom just like this. And to find mass you would have to multiply density and volume. O.K. so, 12 divided by 3 would equal 4, which is on the bottom right hand and 3 multiplied by 4 would equal 12 which is at the top. Uh 12 divided by 4 would be 3, which is at the bottom left hand and it also could be fractional because 12 over 4 would be an improper fraction; it would be 3. And um 12 over 3 would equal 4, same as an improper fraction."
13. N	0:05	"Positive 25 times 6, O.K. so. 150."
14. N	0:04	"Uh positive 12…negative 84."
15. W	0:02	"6"
16. P	0:15	"You can think of it in two ways. (Student counting) 1, 2, 3, O.K. so, it's 1 over 8because 1 piece is being taken away or it could be 7 over 8 because 7 pieces are shaded in."
17. N	0:11	"Uh negative 7"
18. N	0:04	"Oh, uh, negative 4."
19. W	0:08	"Oh, uh, it's a right angle. (Me: How many degrees is that?) O, uh, that's 90."
20. W	0:06	"How many weeks are there in 6 weeks? O.K. so, 7 times 6 would be 42."
21. W	0:17	"Uh, 8, no. Can you repeat the question please? He had 8, oh O.K. so 16."
22. W	0:17	"8 because it doesn't really say that... if her sister's are married. Then, she only has 8 uncles."

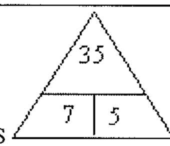
Student #5

Question # & code	Time	Student Response
1. P	0:30	"Uh…6 halves and 3… 3 over half, 9 over 1" (Me: Anything else?) "1 over2"
2. N	0:09	"325 plus125"...(Me: 75) "Uh 500."
3. N	0:07	"Negative 18 or positive 18?" (Me: just 18.) "Plus 5?" (Me: 18+(+5).) "23"
4. N	0:02	"Negative 11."
5. P	0:16	"8 over 1, 8 eighths, 2 halves, 4 quarters."
6. W	0:01	"12"
7. N	0:08	"Uh, negative 32...plus positive 12… uh 20…negative 20."
8. N	0:02	"10"
9. N	0:05	"36"
10. N	0:10	"Negative 81? Subtract?" Me: subtract positive 20.) "Negative 61"
11. N	0:02	"Negative 22."
12. P	0:29	"Uh…uh…3 thirds. Uh…12 divided by 3 equals 4, 12 divided by 4 equals 3, 3 times 4 is 12…yah."
13. N	0:04	"150"
14. N	0:07	"Negative 84…uh, What was it? O, yah, negative 84."
15. W	0:02	"6"
16. P	0:07	"7 eighths."
17. N	0:07	"O, negative 7."
18. N	0:12	"Negative, uh 280 divided by negative 70," (Me:positive70) "Negative 4"
19. W	0:04	"The degree, uh 90."
20. W	0:04	"(Pause) 42"
21. W	0:05	"(Pause) 19"
22. W	0:15	"(Pause) How many uncles? 8" (Me: Your reason or logic for it?) "Because, her father only has sisters and her mother has the only uncles that she'll ever have."

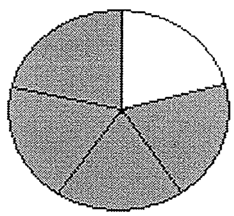
Researcher's Midway Mathematics Test



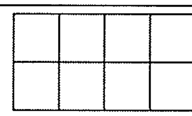
1. State the appropriate equations
2. Add (-5) + (-7) =
3. Subtract (-51) – (+20) =
4. Multiply (-25) (+4) =
5. Divide (+450) / (+15) =



6. State the corresponding equations
7. Add (+13x) + (-6x) =
8. Subtract (+53x) – (-17x) =
9. Multiply (-4x) (+3y) =
10. Divide $(12y^3) / (-4y) =$



11. Identify the fractions
12. What is 25% of 400?
13. How many years in four decades?
14. How many years in 3/4 of a century?
15. What is the sum of half of 16 and a third of 9?



16. State the perimeter of this object
17. Estimate (39) (51) =
18. Estimate 280 / 71 =
19. Estimate the square root of 84
20. How many \$ will you need to add to \$ 29 in order to buy a \$ 45 jacket?
21. Tony has 4 hockey sticks. He gave away 2 hockey sticks last week and 3 hockey sticks the week before last. How many hockey sticks did he have originally?
22. How can Mimi figure out her uncle's age, if she knows that 2 years ago he was 34 years old?

Student #1 Midway Test Transcript, Code and Time (min:sec)

Question # &code	Time	Student Response
1. P	0:44	"Well, it's a whole number. Let's see here. 2 times 4 equals 8. I suppose that could count for an equation. 4 times 2 equals 8. 2 units of 4. That puzzles me. What else could I say? 8divided by 2 equals 4. 8 divided by 4 equals 2." (Me: Why or How does it puzzle you? Is it because it's upright, not sideways?) "Because it's all whole numbers. There is no ones that are coloured. Which was different from what you gave in the past. Because it's all just blank squares. If there is one coloured then you could say that there is 7 plus 1 equals 8. Or 1 plus 7 equals 8. It just threw me off guard."
2. N	0:02	"Negative 12."
3. N	0:22	"Seven, negative 72, wait. No. Subtract 21?" (Me: positive20) "So, negative 31. (pause) Right?" (Me: Negative 51 subtract positive 20.) "Negative 71. So, I was right the first time. I think."
4. N	0:02	"Negative 100"
5. N	0:09	"15, (pause) I think that'll be negative 40."
6. P	0:11	"35 divided by 7 equals 5, 35 divided by 5 equals 7, 7 times 5 equals 35, 5 times 7 equals 35"
7. N	0:07	"7 um 7x"
8. N	0:02	"70x"
9. N	0:03	"Negative 12xy"
10. N	0:14	"12y cubed, 3y? So, negative 3y."
11. P	0:24	"Let's see here. That's 1 out of 5. So, that's 1 over 5 or 4 fifths. If you want to do equations you can say 1 plus 4 equals 5 or 4 plus 1 equals 5. 5 minus 1 equals 4, 5 minus 4 equals 1, and fractions 4 fifths and 1 fifth is mainly what I can think of."
12. W	0:12	"(Pause) 100"
13. W	0:02	"40"
14. W	0:02	"75"
15. W	0:03	"11"
16. P	0:24	"Let's see here. 4 and 1. So, the dimensions would be 2 times 4, 4 times 2. There is 8 in all. Hmm, and the perimeter I suppose would be 1, 2, 3, 4, 10, wait. Wait, no 12. (Counting extremely fast) 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 yah 12."
17. N	0:17	"200 around, because if you times 40 by 50 that equals about, that equals about; no 40 times 50, 4 times 5 equals 20 and 2000."
18. N	0:11	"280 divided by 70 approximation. That would equal about 4 I think."
19. W	0:20	Square root of 84. Let's see here. 9 is 81 and 10 is 100. So, that'll be approximately 9.3 or 2. (Me: No decimals, just whole numbers) "The closest uh, 9."
20. W	0:09	"Let's see here. 45 minus 29, 35, 25, (accenting) 16"
21. W	0:17	"I think he had 3 this week. Can you please, repeat that?" "Nine"
22. W	0:02	"He is 36."

Student #2 Midway Test Transcript, Code and Time (min:sec)

Question #& code	Time	Student Response
1.	0:18	"Uh, one whole, 8-4 equals4, one half of 8 equals 4. I'm not sure."
2. N	0:03	"Uh, negative 12."
3. N	0:13	"Negative, What was the first one?" (Me: (-51)-(+20)) "71, uh, negative 71"
4. N	0:05	"Negative 100"
5. N	0:09	"Uh 450, (pause) 30"
6. P	0:12	"7 times 5 equals 35, 35 divided by 7 equals 5, 35 divided by 5 equals 7 and 5 times 7 is 35"
7. N	0:12	"Did you say positive 6x?" (Me: (+13x)+(-6x)) "U, 7x"
8. N	0: 50	"53x?" (Me: (+53x)–(-17x)) "Uh, 40, I'm not sure. Can I write it down?" (Me: Sure) (I gave paper to the student and repeated the question.) "Uh, oh, 70x."
9. N	0: 10	(Whispering something very quietly, then) "Positive 3y?" (Me: (-4x)(+3y)) "Negative 12xy"
10. N	0:04	"Negative $3y^2$"
11. P	0:16	"Uh 1 fifth, 5 over, no, uh 4 over 5, um, That's it. One fifth and 4 over 5."
12. W	0:10	"100 um, 40."
13. W	0:05	"Uh 400 years. No, 40 years."
14. W	0:13	(Pause) "25 years?" (Me: three quarters of a century.) "Oh, 75 years."
15. W	0:07	"Uh 6"
16. P	0:04	"12"
17. N	0:07	"Uh, 40 times 50, uh, 200"
18. N	0:19	""300 times? What was the other? (Me: Estimate 280 divided by 71.) "300 divided by 70, uh 40."
19. W	0:03	"About 9"
20. W	0:39	"45-29, uh, (Pause) Can you repeat the question?" (I repeated the question.) (Pause) "16 dollars."
21. W	0:19	"Can you repeat the question again?" (I repeated the question.) "9"
22. W	0:06	"His uncle is 36 now."

Student #3 Midway Test Transcript, Code and Time (min:sec)

Question # &code	Time	Student Response
1. P	0:13	"Uh, one whole, 4 plus 4 equal 8, uh, 1 over 1, negative 1 over negative 1."
2. N	0:02	"Negative 12. "
3. N	0:05	"Negative 51 take away positive 20, uh, negative 31."
4. N	0:03	"Negative 100."
5. N	0:20	"Negative 450? Uh positive 450 divided by positive 15, uh, no, negative, a positive 30."
6. P	0:10	"7 times 5 equals 35, 5 times 7 equals 35, 35 divided by 7 equals 5, 35 divided by 5 equals 7."
7. N	0:04	"Positive 7x."
8. N	0:13	"Add 17? Can you repeat it?" (I repeated the question.) "Oh 70 positive 70."
9. N	0:05	"12xy, oh, negative 12xy."
10. N	0:08	"Uh, $3y^2$ oh, negative $3y^2$."
11. P	0:06	"4 fifth of 1 fifth."
12. W	0:14	"A (pause) a 100."
13. W	0:02	"40"
14. W	0:05	"75"
15. W	0:09	"Can you repeat it please?" (I repeated the question.) "Oh, 12, oh 11."
16. P	0:03	"12"
17. N	0:16	"Oh, 39 times 51, oh so, wait. Around 1600, 1700."
18. N	0:08	"Uh, 71 into 280, so, that will be about 4."
19. W	0:03	"84, it will be about 9."
20. W	0:14	(Very quietly) "Uh, O.K. 1, 2, 15, 29, 45, 1," (Accenting) "16"
21. W	0:03	"Oh, 9."
22. W	0:17	"Uh, 36. She can add 2 to 34 and she'll get 36."

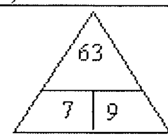
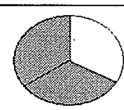
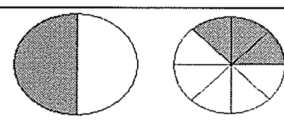
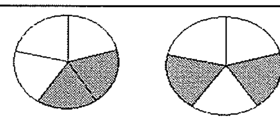
Student #4 Midway Test Transcript, Code and Time (min:sec)

Question # & code	Time	Student Response
1. P	0:41	"O.K. I would say 2 times 4 would equal 8 and 2+2+2+2 or 2 to the power, no that would be wrong. Um 2 times 4, 4 times 2, 2+2+2+2, and 1 added 8 times, (moving fingers quickly) 1+1+1+1+1+1+1+1, and 4 plus 4, and 6 plus 2."
2. N	0:02	"Negative 14."
3. N	0:04	"Negative oh, uh, negative 31."
4. N	0:04	"Uh, negative 100."
5. N	0:20	"Uh, Did you say negative 400?" (I repeated the question." Uh 30. Or wait. No, yah, no divided by 15. Yah, 30."
6. P	0:11	"Wait. I can't see." (I put the triangle closer to the student.) "Wait. O.K. 5 times 7 would be 35, 35 divided by 7 would be 5, 35 divided by 5 would be 7."
7. N	0:06	"Oh, uh, 7x."
8. N	0:08	"53x take away negative (pause)?" (Me: Take away negative 17x.) "Oh, uh, 70x."
9. N	0:05	"Uh, negative 12xy."
10. N	0:10	"O, uh, 3y over negative 1."
11. P	0:21	"It's uh, divided into 5? O.K. 1 over 5, 5, sorry, O.K. 1 over 5, 4 over 5 uh, Can I also add it?" (Me: If you wish.) "O.K. 1 plus 5. I'm sorry. 1+4=5, 5-1=4, 5-4=1."
12. W	0:18	"25% of 400? Uh, 25%, oh, oh mm, 100."
13. W	0:02	"40"
14. W	0:03	"75"
15. W	0:05	"Half of 16 and a third of 9? Oh ah, 11."
16. P	0:10	"Uh, perimeter? O.K. So, 2 plus, O.K. 4 plus 8 would be 12."
17. N	0:33	"39 times 51?" (Me: Yes. Estimate it.) "Uh, wait, oh, plus 51?" (I repeated the question.) "Oh, O.K. 40 times 50 would be 20, so it's 200. No, 2000."
18. N	0:04	"71?" (Me: Yes, but I want it estimated.) "O.K. 40."
19. W	0:04	"Estimate the square. Oh, approximately 9."
20. W	0:04	"Uh 16."
21. W	0:13	"Tony has 4 hockey sticks? O.K. So, he gave away 2 before?" (Pause, then, I repeated the question.) "Uh, 9, (student repeated) 9."
22. W	0:05	"She adds 2 to 34 which would be 36."

Student #5 Midway Test Transcript, Code and Time (min:sec)

Question # &code	Time	Student Response
1. P	0:13	"Uh, um, 2 times 4, 1 times 8, (Pause.) I think so, yah."
2. N	0:06	"Uh, Negative 12."
3. N	0:06	"Negative 71."
4. N	0:02	"Negative 80."
5. N	0:08	"Negative 15?" (Me: No, positive.) "30"
6. P	0:18	"35÷7=5, 35÷5=7, 7·5=35, 7·5=35, 5·7=35."
7. N	0:09	"Positive 7x."
8. N	0:12	(Pause.) "36x"
9. N	0:10	"What was it? Sorry. (I repeated the question.) "Negative 12xy."
10. N	0:16	"Hmm, negative, negative y, no, $12y^2$? (I repeated the question.) "Negative $3y^2$."
11. P	0:16	"1 whole minus 1 fifth equals 4 fifths, 1 whole minus 4 fifths equals 1 fifth, I fifth plus 4 fifths equal 1 whole, 4 fifths plus 1 fifth equal a whole."
12. W	0:27	(Pause.) "90. Wait. 25% of 400? (I repeated the question.) "Oh, a hundred."
13. W	0:03	"40"
14. W	0:02	"75"
15. W	0:23	"What was that saying?" (I repeated the question.) "Is this a fraction question?" (Me: You could treat it as such.) "Half of 16?" (I repeated the question again.) "Eleven."
16. P	0:05	"12"
17. N	0:19	(Pause.) "Times 51, 1 thousand, about. Wait. 30 what?" (I repeated the question.) "Oh, uh, 2000."
18. N	0:16	(Pause.) "280?" (I repeated the question.) "Uh, 4."
19. W	0:03	"Approximately 9."
20. W	0:14	"Can you say that again? Sorry." (I repeated the question.) "Uh 16."
21. W	0:14	"Uh, one more time. Sorry." (I repeated the question.) "Uh, 9."
22. W	0:13	"Uh, 2 years ago, he was how old?" (Me: 2 years ago, he was 34.) "Uh, 36."

Researcher's Final Mathematics Test

1.	Add 295 + 35 =
2.	Subtract 296 – 34 =
3.	Multiply (-25) (-5) =
4.	Divide (240) / (-60) =
5.	State the equations 
6.	How many wheels are on 5 cars?
7.	How much does each ticket cost if the total for 6 tickets is $ 30 ?
8.	Multiply by (-3m) the polynomial (2m-5y+9)
9.	Divide by (-2x) the polynomial (-2d+4x-10)
10.	There were 25 questions on the test. Walter got 80% of them correct. How many questions did he get correct?
11.	Tom's mother is 30 years old and his father is 34 years old. Tom's age is the square root of his mother's and his father's age combined. How old is Tom?
12.	Identify the fractions. 
13.	Peter had 12 hockey sticks. How many hockey sticks would you say Peter gave away, if he told you that he now has one third of the original amount?
14.	Mary's mother is 4 decades old. Mary is 2 years more than a quarter of her mother's age. How old is Mary?
15.	Add (shaded area) 
16.	Subtract (shaded area) 
17.	What is the perimeter of a 3m long and 5m wide room?
18.	How many eggs will your mother need if she wants to make three cakes and if each cake uses half-a-dozen eggs.
19.	What is your chance of winning a spelling contest if including you there are 32 students entering?
20.	There are 8 gift-baskets of apples, bananas and pears with the following label on each (5a + 3b + 4p). How many of each does the storekeeper need in order to fill all 8 baskets?
21.	What method of problem solving would you use? Why would you choose that particular method?
22.	How many square feet of carpet do you need in order to cover the floor if your room is 9 feet wide and 11 feet long?

Student #2 Post- Test Transcript, Code and Time (min:sec)

Question # & code	Time	Student Response
1. N	0:03	"Um 315"
2. N	0:13	"Uh, 200 (Pause.) I'm sorry. What?" (I repeated the question.) "263, 262"
3. N	0:24	"Negative 115, ah wait. Is it negative 25 times negative 5? Oh 125". (Me: Why did you change your mind?) "I'm not sure."
4. N	0:06	"Uh negative 40. No. Negative 4."
5. P	0:11	"63 divided by 5 is 9, 63 divided by 9 is7, uh 9 times 7 equals 63, 7 times 9 is 63."
6. W	0:04	"Uh 20."
7. W	0:02	"Five"
8. N	0:35	"Uh negative 2m (pause) um, can I see it?" (I showed the question.) (Pause) "Um. Negative 6msquared plus 15my minus 27m."
9. N	0:22	"What am I dividing by?" (Me: negative 2x) "Negative 2x, so d over x plus uh 2 plus 10 over, no 5 over x."
10. W	1:20	"Uh (Pause) I'm not sure." (I repeated the question.) "Um 80% of 25 so , Can I have paper please?" (Pause. Student writing) "Um, he got 20".(Me: 20 correct?) "Yah."
11. W	0:02	"Uh 8."
12. P	0:07	"Uh, one third, two thirds, and that's it."
13. W	0:03	"Uh 4."
14. W	0:31	"Did you say Mary is 2 years? Can you repeat it?" (I repeated the question.) "Mary is more than - ?" (Me: 2 more than a quarter of her mother's age) "Uh (pause) 12."
15. P	0:59	"Uh (pause) one out of 8, uh one over 8." (Me: How did you do that?) "I put the half and the shaded area of the other together and I got one eight." (Me: So the total shaded area is 1 out of 8.) "Yah, oh no, it's 7 out of 8."
16. P	0:42	"Uh (pause) uh 6 out of 10." (Me: The shaded area? You are subtracting them?) "So you are subtracting 2 fifths and 2 fifths? Zero. O.K." (Me: So that's what you got?) "Yah."
17. W	0:08	"The area?" (Me: Perimeter.) "Uh 16."
18. W	0:04	"18 eggs."
19. W	0:02	"1 out of 32."
20. W	0:38	"Can I see the question?" (Pause. Student looking at the question.) "Uh, uh 40a plus 24b plus 32p."
21. W	0:16	"Uh I multiplied how many, oh, I multiplied the label by how many baskets there was." (Me: Why?) "Because it says that each basket I think has that label."
22. W	0:08	(Room is 12 by 8), (Pause) 96 meters squared."

Student #3 Post- Test Transcript, Code and Time (min:sec)

Question # & code	Time	Student Response
1. N	0:02	"Uh 325."
2. N	0:07	"O.K. so 262."
3. N	0:10	"Negative…Can you repeat the second part?" (I repeated the part.) "Oh positive 125."
4. N	0:06	"Uh 4…uh negative 4."
5. P	0:09	"Uh 7 times 9 equals 63, 9times 7 equals 63, 63 divided by 7 equals 9, 63 divided by 9 equals 7."
6. W	0:02	"Uh 20."
7. W	0:02	"Uh 5 dollars each."
8. N	0:59	"Can you repeat it please?" (I repeated the question) "Uh Can I see the question?" (Student looked at the question.) "O.K. so negative 6m plus 15m or plus 15mx negative 27m, Yah."
9. N	0:24	"O.K. so negative 2d minus 2x, yah, minus 10."
10. W	0:13	"Uh (pause) uh 20 or wait, 22."
11. W	0:32	"Um two ages combined. O.K. (pause) I don't know." (I read the question again.) "Oh, O.K. He is 8."
12. P	0:05	"Two thirds or one third."
13. W	0:05	"He has 4 left. So he gave away 8."
14. W	0:04	"40 years old. She is 12 years old."
15. P	0:07	(Pause.) "So seven eighths."
16. P	0:17	(Student counting parts.) "1/5 wait, nothing. Zero." (Me: Why did you change your mind?) "Because I saw. (Again counting) Yah, zero."
17. W	0:05	"O.K. 16."
18. W	0:14	(Pause.) "3 She wants to make how many cakes?" (Me: 3cakes.) "Yah and half a dozen?" (Me: Half a dozen each.) "O.K. 18 eggs."
19. W	0:02	"I out of 32."
20. W	0:51	"Can you repeat the question please?" (I repeated it.) "So, 5 apple, I don't know." (I showed the label to the student.) "Oh, so O.K., O. Ok. So he needs 40 apples 24 bananas and 32 pears."
21. W	0:14	"Multiplication. So I 8 times multiplied the total number. Because that's what I needed to solve the problem."
22. W	0:06	"99"

Student #4 Post- Test Transcript, Code and Time (min:sec)

Question # code	Time	Student Response
1. N	0:17	"295 plus 35 would give me 60, no, 295?" (Me: 295+35) "O.K. it would give me 330."
2. N	0:07	"Uh 296-34 O.K. 260. no 296 subtract 34 uh O.K. 232."
3. N	0:04	"Uh positive 125."
4. N	0:09	"260 divided by negative 60? Uh (pause) oh, uh, negative 4."
5. P	0:10	"O.K. 7times 9 is 63, 63 divided by 7 is 9, 63 divided by 9 is 7."
6. W	0:04	"So hard are 20."
7. W	0:02	"Uh 5."
8. N	0:35	"Multiply by negative 3m (pause) Can I see the question" "O.K. uh negative 12m squared minus 15, no plus 15m, no, yah plus 15my plus, no minus 29m."
9. N	0:40	"May I see the question please? Dividing by negative 2x O.K. d/x plus uh 2 subtract by, plus 2/x, or did I do it wrong. Yah, I forgot how to divide."
10. W	0:19	"80%? O.K. Um 80 divided by 20 (pause) 80 divided by 4 equals 20, because 4x25 equals 100. So 80 over 100." (Me: So your answer is? How many did he get correct?) "Twenty."
11. W	0:08	(Pause) "The mother is 30. Oh 8."
12. P	0:10	"O.K. uh one over 3 or yah one third or 2 over 3."
13. W	0:10	"Peter had 12? O.K. He has 1/3 of the original amount left that would be 4 over 12 and he gave a way 8."
14. W	0:05	"2 years older than a quarter? That would be 12."
15. P	0:19	"Uh O.K. so wait 4 O.K. 3 eighth and one half would give me um (pause) 3 eight plus one half equals 7 eighth."
16. P	0:22	"O.K. 2 fifth minus or 2 fifth minus (laughing) zero." (Me: minus zero?) "No 2 fifth minus 2 fifth equals zero."
17. W	0:15	"15 wait, wait, what? The room is 3 by 5 and you have to find the area?" (Me: No, you have to find the perimeter.) "Uh, 16."
18. W	0:04	"Half a dozen? Three cakes? 18."
19. W	0:02	"One thirty twoth. How do you say that?"
20. W	1:19	"Could you repeat the question please?" (I repeated it.) "How many of each? (pause) Oh 40 apples wait, 40 apples to fill up one baskes and 24 bananas and wait; 40 apples 24 bananas and 32 pears."
21. W	0:32	"Multiplication each, multiply each food item by 8 and you would get the total amount. Why? Because it makes the most sense, because if you take 8 baskets and each one of them has that total amount then for like, uh; So then there are going to be 40 apples in total if you have 8 baskets and the formula is 5a+3b+4p. Then you would have; this is the total in 8 baskets 40a+24b+32p."
22. W	0:08	"Got it, got it, 11 feet long? 99 square feet. Wait, let me repeat that; 99 square feet. O.K. I got it."

Student #5 Post- Test Transcript, Code and Time (min:sec)

Question # & code	Time	Student Response
1. N	0:06	(Pause.) "Uh 330."
2. N	0:29	(Pause.) "296 take away 34? (pause) 252."
3. N	0:05	"Times? Negative? A hundred twenty five."
4. N	0:08	"Positive 240? Negative4."
5. P	0:14	"O.K. uh 63 divided by 9 equal 7, 63 divided by 7 equal 9, 7 times 9 equal 63, 9 times 7 equal 63."
6. W	0:03	"20"
7. W	0:01	"5 dollars"
8. N	0:58	"Could you repeat that?" (I repeated the question.) "Can I see? Negative 3m, Oh, uh negative 6m squared positive 15m oh, positive 3my no, positive 15my plus negative 27m.
9. N	0:42	"Multiply by what?" (Me: negative 2x) "4dx-8dx is it –2x, negative, no, positive 20x."
10. W	0:19	(Pause) "25questions?" (Me: Yes.) "Twenty."
11. W	0:46	"The two ages combined? The square of those? (Me: the square root) "What were the ages again? 30 so 5. Five and then the no. So I do square root and then add or add and then square root? (Me: I can't tell you that. Sorry.) "Can I hear the question again?" (I repeated it.) "Oh, 8."
12. P	0:14	"Ah the shaded or non-shaded?" (Me: just whatever fractions you see there) "Uh 2 thirds and one third."
13. W	0:26	"How many hockey sticks?" (I repeated the question.) "He has one third left?" (Me: One third left. Yes.) "Uh 4." (Me: He gave away 4?) "Oh no. He gave away 8. He still has 4."
14. W	0:11	"Could you repeat that?" (I repeated it.) "Twelve."
15. P	0:10	"Uh 7 eights."
16. P	0:10	"Uh, zero."
17. W	0:12	"Perimeter of, what are the dimensions?" (I repeated the dimensions.) "16 meters perimeter."
18. W	0:03	"18 eggs."
19. W	0:06	"One thirty two, uh one in thirty two."
20. W	1:28	"Could you repeat that?" (I repeated it.) "What were the labels again? Sorry." (Pause) "96 Uh, Can I see the label? What was after the tag?" "O.K. uh, 40 apples, (pause) 24 bananas and 32 pears."
21. W	0:08	"Multiplication. 8 times each set. Because it gives the solution."
22. W	0:04	"99 feet squared."

Appendix H:
Field Notes

Researcher's Observations were taken during certain but not all Oral Mathematics drill activities.

Activity session after Quiz #2.
All five students present.
Activity sheet #1 seems to be too easy for them. Some students even commented that the questions were "so easy".

Activity session after Quiz #3
Student #1 was missing.
2nd overhead sheet was used – slightly increased in difficulty from sheet #1.
Students enjoyed the activities.

Activity session after Quiz #4
All five students present.
Did all exercises without the overhead projector.
Students replied quite quickly. The replies were mostly correct. If I got more than one reply to a question we, together figured out which reply was correct.
Most students said they preferred it without the overhead projector. (One student, Student #3, stated preference for seeing the questions, 4 stated preference to hearing it only.)

Activity session after Quiz#5
Student #5 was missing.
Number strand worksheet #3 was introduced (fractions: addition, subtraction, multiplication, and division).
Students said the quiz was difficult.
To ease the activities, we did pictorial representation of fractional operations.
Student #1 was quiet throughout the entire time, seemed to be listening, watching, and absorbing.
Student#2 was very excited about the activities and explanations. Later on Student #2 asked if you could use common denominators when you add and subtract.
At the start of the activity session Student #4 asked if "of" means "multiply, then Student #3 said, "Oh! That's what that means."
All four students were super eager to give responses. They all responded with excitement to the end.
They all said: "Thank you." as they were leaving.

Activity session after Quiz #9
All five students were present.
After the explanations the pictorial patterns seemed too easy for all. So did the rest of the activities.

Activity session after Quiz #10

All five students were present.
Everyone completed the quiz quite fast.
Activities seemed too easy. Students seemed to be preoccupied (not paying attention to the activities all the time).

Activity session after Quiz #11
All five students were present.
Activity set #4 does not seem to hold their interest any more.

Activity session after Quiz #12
All five students were present.
Oral Mathematics activity set #5 seemed to have created new interest. All five students were interested in the activities and asked good questions. We discussed adding constant + constant vs. variable + constant

Activity session after Quiz #16
Student#5 was missing.
Student #3 had an instant answer to almost all the questions and most of them were correct. The rest seemed intimidated by the speed. We redid some questions and asked Student #3 to slow down a bit and let the others also have a chance to answer.

Activity session after Quiz #17
All five students were present.
Today seemed to be a speed competition amongst the five of them but especially between student #1 and#3.

Activity session after Quiz #18
All five students were present.
Activity set #7 is based on polynomials. Students found it a bit challenging but they remembered most of it from grade 8. We reviewed the concepts of addition, subtraction, multiplication, and division of two single term polynomials (monomials).

Activity session after Quiz #19
All five students were present.
Polynomial activities seemed to be a little easier today, after yesterday's overview. Most of the replies were correct.

Activity session after Quiz #20
All five students were present.
Today seemed like another competition, mostly between Student #3 and 4 at the start, but Student #1 soon joined in with very quick and accurate replies.

Activity session after Quiz #28
Student#2 was absent.
Started geometry today.
It was quite slow going. They needed some review.

Activity session after Quiz #29
All five students were present.
Student #1 was doing quick counting of squares out loud (counting each unit square).
Student #4 was doing quick calculations out loud.

Activity session after Quiz #30
All five students were present.
All five eagerly participated.
Student #3 was replying quicker than the others. Student #1 and 2 quite quick with some replies.

Word Problems–session 1
All five students were present.
All questions were calculated orally/mentally. No pen (pencil), paper, calculator or any other devices were used by anyone.
Student #1 and #3 were competing – trying to outdo each other in speed.
Student #2 objected to the almost unrecognizable fast talk.
Student #4 and #5 started with a great speed but then gave up. They repeated the answers afterward.
Student #4 sometimes paused wanting more time processing the information.
Student #2 preferred a slower pace – time for processing information.
The students have seen these questions (questions 1 – 13) on previous activity sheets.
All replies were instant replies.
No quiz preceded this review session.

Word Problems and Polynomials- session 2
Student #2 and #3 did not attend. (They notified me that they had another after-school activity to attend.)
Quiz was given today – 10 questions. There were 5 completely new word problems amongst the questions (not just different numbers but completely different word problems).
All three students were eager to calculate during the drill session. These questions were numbered 14 – 26. It was good to hear the students apply some of the techniques used during the previous Oral Mathematics drill sessions.
Question #14–correct instant reply by all.
Question #15–correct instant reply by all. This time I asked the students how they figured out the answer. Three voices were stating out loud (Student #4 was the loudest) that the triple of 2 is 6 and one less is 5.
Questions #16, 17 and 18 were review questions.
Question #19 Student #4 said instantly "49".
How did you get that? – I asked.
Student #1 and 5 said: "No, 29."
Student #4 said: "7 times 7 is 49."
What does the question ask? - I asked.
"Or is it two separate squares?" Student #4 asked.

Let's see, – I said – it states that her age is the sum of the squares of their ages. What does that mean?
All three replied: "Add 4 plus 25 together."
I said, - Yes, and when you read a question, be sure to pay attention to the exact wording. So, sum of the squares means..?
Student #1: Square the numbers and add them.
I said, O.K. so, watching for the wording of the question, the square of the sum is what?
Student #4: "Calculate it first and square the sum of the two numbers 2+5 which is 7 so it's 49, but we had to get the sum of the squares of their ages, so it's 2 squared plus 5 squared and that's 29."
Question #20 correct instant reply by all. Then, Student #4 asked: "How can a 121 year old man have an 11 year old grandson?" We discussed that subject.
Questions 21 – 24 were review questions and the students found them easy.
Question #25 very quick replies.
Student #1 replied: "That's 33; 80 minus 47 is 33"
Student #4: "That's 147."
Student #4 and 5: "No, that's 127."
How did you get that? – I asked.
Student #5: "The uncle is 47 and the grandfather is 80, that's 127."
Student #4: "The uncle is 3 less than a half-century, that's 47 years old and the grandfather is 2 decades short of a century, that's 80 years, so that's 127." After a pause, "No, wait, the difference in their age is; that's 80 minus 47, that's 33."

Appendix I:
Survey Data and Coding

Initial Student Survey Questions and Student Replies

Question # 1 (Difficulty Level) Do you find mathematics easy or difficult? Explain why.
Student # 1 "If I am given a formula to work with or work with simple algebra, math, I can usually do very well. Changing fractions to decimals, improper fractions to mixed fractions, etc. I find easy for I understand math fairly well when given formulas or can find simple patterns if I am familiar with them."
Student # 2 "Easy because I love math & I easily understand concepts even though I'm not as good in mental math."
Student # 3 "I find it easy, because you have little things to memorize such as formulas."
Student # 4 "Although, I find math easy, some topics such as long division and square root hard. I find these hard to do without a calculator for they require a lot of mental math and patience."
Student # 5 "I find math easy because it comes naturally to me."

Question # 2 (Difficulty Level) What mathematical topics do you find easy?
Student # 1 "Algebra (single) expressions, Pythagorean theorem, calculating Surface Areas"
Student # 2 "Algebra, Geometry and just basic math"
Student # 3 "I find FRACTIONS, ALGEBRA, and SQUARE ROOTS, PYTHAGOREAN THEOREM"
Student # 4 "I find fractions, division, multiplication, addition, subtraction, exponents, geometry, decimals, algebra."
Student # 5 "I find most math easy especially Surface Area & integers."

Question # 3 (Difficulty Level) What do you think makes those topics you named easy for you?
Student # 1 "I find these topics easy for there are usually a set of rules or formula to follow which I can apply and makes sense to me."
Student # 2 "because the concept is easy to understand"
Student # 3 "I am easily able to memorize how to do these in my head and on a calculator"
Student # 4 "I have done them before and I know most of the basic concept."
Student # 5 "I think it's because I have already done them."

Question # 4 (Difficulty Level) What mathematical topics do you find difficult?
Student # 1 "perhaps plotting graphs, or information relating to graphs and problem solving."
Student # 2 "Trigonometry"
Student # 3 "Surface Area with 3-D composite solids"
Student # 4 "Square root, long division, multiplication of large numbers."
Student # 5 "I find fractions and the Pythagorean theorem kind of difficult."

Question # 5 (Difficulty Level) What do you think makes those topics difficult?
Student # 1 "I believe it is because Problem Solving may require creative thinking instead of merely analysis. For graphing, I have little visual process ability"
Student # 2 "It's more complicated & you have to be very precise."
Student # 3 "Hard for me to figure out what formulas to use and which numbers you have to do with the formula."
Student # 4 "they require a lot of time, and concentration."
Student # 5 "The way the formulas are laid out."

Question # 6 (Assignments) When your teacher assigns math exercises to be done in class, how much of the work can you do on your own?
Student # 1 "It depends if I plan to (1) guess and check (2) break down the formulas step by step (3) try to do simple calculation in my head to write on paper. I do not like punching a whole equation at once in the calculation for we were taught to show all our work. I understand the info usually, however I may not finish the work in class"
Student # 2 "I can usually finish it within class time."
Student # 3 "I can do at least 90%of work on my own"
Student # 4 "Most of it unless it's multiplication of decimals division of decimals, long division, square root."
Student # 5 "I can do most to all of the work very easily."

Question # 7 (Assignments) Describe the method(s) (strategy) you use to solve the math problems (exercises). These problems (exercises) can be word problems, geometry questions, algebra or simple arithmetic questions.
Student # 1 "Word problems I break it down into small, easy blocks of information and write what is discovered through simple analysis. Algebra I may look if x and y equal a certain sum, what y increases by each time, etc."
Student # 2 "I just solve all of it then I go back & check."
Student # 3 "I read it out in my head, solve the problem step-by-step and figure it out."
Student # 4 "I could write out the problem, and figure it out as best as I can, step by step."
Student # 5 "I will do as much as I can mentally except with the triple digits and decimal question."

Question # 8 (Assignments) When you need help with your class work, what type of help do you need?
Student # 1 "Usually problem solving work or work that requires thinking outside the box or logically. I need to be taught how to do a formula or those complex questions to be able to understand it for I cannot think in math terms to solve difficult questions."
Student # 2 "I just check the book & instructions just so I'm clear with what to do."
Student # 3 "Understanding the question."
Student # 4 "help from the calculator, and help from teachers/parents."
Student # 5 "I only need a simple guide for the one question."

Question # 9 (Assignments) When you get homework in mathematics, what method(s) (strategy) do you use to complete each question? If you use a variety, state when you use each.
Student # 1 "I may guess and check + I usually breakdown the formula step by writing down specific answers, instead of punching it all into a big block of information. I show my work."
Student # 2 "I read the problem carefully & I think of the steps on how to solve it."
Student # 3 "Use the formula, or if it isn't that complicated I would use my head"
Student # 4 "I use guess and check, and step by step methods."
Student # 5 "I do the formula needed or if it's an easy question I will do it in my head."

Question # 10 (Assignments) Why do you use that particular method of doing math exercises?
Student # 1 "We were taught to do that, to break the formulas down into simple substances to see where we went wrong.
Student # 2 "Because it's easy & it takes me a small amount of time."
Student # 3 "Because it is efficient and easy"
Student # 4 "For they make solving the problem easier through observation."
Student # 5 "It's easier and I don't find it difficult to answer"

Question # 11 (Assignments) What portion of your homework do you usually manage to complete?
Student # 1 "What is taught and does not require too much creative thinking outside the box."
Student # 2 "I easily finish homework once it's assigned & if we get enough class time to work on it"
Student # 3 "All of it."
Student # 4 "95% of the homework I usually get done unless I forget to do."
Student # 5 "All of it, 90 - -100%"

Question # 12 (Assignments) What portion of your completed homework is usually correct?
Student # 1 "Those, which we are taught or learn. I may make simple mistakes with formulas or rules learned, however, not often. Again, complex problem solving"
Student # 2 "mostly all of them."
Student # 3 "about 75 – 90%"
Student # 4 "4/5ths of it is usually correct."
Student # 5 "Most of it, 90 – 100%"

Question # 13 (Assignments) How much time does it usually take to do your math homework?
Student # 1 "An hour or two, depending"
Student # 2 "about half an hour, depends how much is assigned"
Student # 3 "Depends on how much we get. Usually 10 – 20 minutes."
Student # 4 "about 1 hour – 30 min."
Student # 5 "Depending on how many questions, 5 – 20 min."

Question # 14 (Test/Quiz) When you write a math test or quiz, do you usually manage to complete it? Why? Or Why not?
Student # 1 "Yes, because I know the answers and know how she wants us to show our work."
Student # 2 "Yes because I start with the problems that take me longer & I quickly breeze through the easy problems."
Student # 3 "Yes, but sometimes I either rush (don't go over it) or guess because I run out of time."
Student # 4 "Yes but sometimes the test is too long or the time is too short."
Student # 5 "Yes, I find the questions easy or understandably easy."

Question # 15 (Test/Quiz) What portion of your math test or quiz is usually correct?
Student # 1 "That which I studied, Problem Solving can be the annoyance."
Student # 2 "usually 90% of it is correct"
Student # 3 "70% - 85%"
Student # 4 "about 3/4ths of the testes and quizzes"
Student # 5 "All to most 85% - 100%"

Question # 16 (Calculation Preference) Do you prefer to work out your math problem in your head **or** by using a pen/pencil and a piece of paper **or** by using your calculator? Explain why?
Student # 1 "I prefer using a pen or pencil and partially in my head if dealing with simple problems. I do not like using the calculator for then it is a big, complex box of information that I cannot understand. Pencil and paper is good to breakdown the information."
Student # 2 "I prefer to use pen/pencil or calculator because I'm not so good in mental math. It takes me a while to come up with the correct answer if I don't have pen or paper."
Student # 3 "-Pen/pencil and paper because then I can write it out, see my errors, and make sure I'm doing it right."
Student # 4 "I do the problem in my head and if the problem is too hard then I will do it on a piece of paper (which I prefer) for it makes doing the problem easier."
Student # 5 "I do the questions that I can in my head and the difficult questions on a calculator"

Final Student Survey Questions and Student Replies

Question # 1 (Oral Math) Did you find the oral mathematics drills easy or difficult? Why?
Student # 1 "Depends if I look at the written work difficult by itself being nurtured by words than by sound, it is hard to visualize numbers on the test. I did well during overhead for benefit of viewing information. Just tried during tests."
Student # 2 "Easy because some of it is just basic math & some of it we've already done."
Student # 3 "Difficult, because I am used to doing everything on paper or calculator"
Student # 4 "difficult for I had previously missed about 6 – 7 classes so I couldn't keep up."
Student # 5 "Easy, because with the repetition of the problems it became easier."

Question # 2 (Oral Math) Did you find the oral mathematics drills help improve your <u>accuracy</u> with simple operations? Why? Or Why not?
Student # 1 I would not know! I have no specific examples available to me, however, judging from the final test, I seem to be able to do word problems a bit more a pl."
Student # 2 "Yes it did because we were taught how to look at the problems differently which made it much easier."
Student # 3 "Yes, because then you are mentally prepared and able to do them"
Student # 4 "Yes, for the drills explained how to solve and understand a problem."
Student # 5 "Yes, with some of the drills such as the % of a # it became easier in my daily life."

Question # 3 (Oral Math) Did you find the oral mathematics drills help improve your <u>speed</u> while performing simple operations? Why? Or Why not?
Student # 1 "Not in particular since the tests required memorization due to repetition, and the overhead I think helped deform me. I was more for memorization and speed; not always for accuracy once I understood how something worked."
Student # 2 "Yes because by doing the oral drills, it helped me think of it faster."
Student # 3 "Yes, because you would be ready and to do it"
Student # 4 "Yes for the repetition of the exercise helped to understand it better."
Student # 5 "Yes with repetition it was easier to do all operations."

Question # 4 (Oral Math) Did the oral mathematics drills have any influence on your <u>class work</u>? How?
Student # 1 "Not in particular; maybe because what we did seemed slightly detached from the curriculum in some way a lack of rules taken?"
Student # 2 "Yes because the stuff that we do in class is fairly the same."
Student # 3 "Yes, it's enabled me to do my work faster"
Student # 4 "Yes for it brought new perspective to me and it made math easier"
Student # 5 "Yes, I was able to answer numerical questions easier and faster"

Question # 5 (Oral Math) Did the oral mathematics drills have any influence on your <u>homework</u>? How?

Student # 1 "I do not think so, if any maybe I wait...I think so since math homework takes or feels to take a shorter amount of time now, it was a subtle change."
Student # 2 "Yes it made me do homework faster because like I've said, what we do in class is fairly the same material."
Student # 3 "No, because I use calculator just to make sure"
Student # 4 "Yes for it made me faster & more efficient at my work than before."
Student # 5 "Yes, I was able to do the numerical questions in my head without a calculator."

Question # 6 (Oral Math) Did the oral mathematics drills have any influence on how you solve questions on a math test or quiz? How?
Student # 1 "If there were any, they were extremely subtle."
Student # 2 "It would have if we had math tests and quizzes that are exactly the same but because the material was covered at different times, then it mostly didn't help me"
Student # 3 "No, I always use calculator, just so I don't get it wrong"
Student # 4 "Yes, by helping me dissect the problem and piece it back together."
Student # 5 "Yes, specifically with the % of other #s.

Question # 7 (Assignments) When your teacher assigns math exercises to be done in class, how much of the work can you do on your own? (7.1) Is that the same as you what you could do before you were expose to oral mathematics drills?
Student # 1 "Most of it if I understand it; it is not often I do not understand something (since I listen to the teacher's explanations in class). (7.1) Yes, I believe so. Math is about knowing the building blocks of the work, not so much the activity."
Student # 2 "I can finish most of the exercises within the given class time. (7.1) It was basically the same but I think this time, I can be more efficient & some of the processes are automatic."
Student # 3 "All or most of it. (7.1) Yes, it is the same as what I could do before."
Student # 4 "about 3/4ths (7.1) No, for I could only do about 3/10ths of it before."
Student # 5 "I most likely can do all or at least most of it (7.1) Yes"

Question # 8 (Calculation Preference) Describe the method (strategy) you use to solve the math problems (exercises) now.
Student # 1 "I try to use mental math abilities such as 8 x 12, seeing it as (8x10) + (8x2) = 80 + 16 + 96
Student # 2 I have to understand the problem but once I get I can answer it instantly."
Student # 3 "I think about how I should do it, and do it."
Student # 4 "understanding the problem, solving it mentally, & answering it."
Student # 5 "I use the same ones except for percents of numbers I use the strategy I learned from the oral math."

Question # 9 (Assignments) When you need help with your class work, what type of help do you need?
Student # 1 "I just need the foundations or logic to be put in my head"
Student # 2 "I don't usually get help, but when I do I just ask for directions/instructions."
Student # 3 "Understanding and solving it"

Student # 4 "help with understanding the problem."
Student # 5 "I would only need basic, check over help."

Question # 10 (Calculation Preference) When you get homework in mathematics, what method (strategy) do you use to complete each question?
Student # 1 "I try to use my head to solve questions, go over notes, do addition, subtraction, multiplication, division, etc."
Student # 2 "I use the same method as my answer in #8."
Student # 3 "The Right method used to find answer"
Student # 4 "Understanding the question, looking at the problem, and trying to solve it mentally before writing it down."
Student # 5 "What ever method is needed to finish the question."

Question # 11 (Calculation Prefernce) Why do you use that particular method of doing math exercises?
Student # 1 "I prefer to do calculation in my head for I see it more beneficial to me in the long run"
Student # 2 "Because it's what I'm familiar with & it's easier for me."
Student # 3 "Because it's effective and efficient"
Student # 4 "It makes it easier to do the problem. And because I've been taught to do it like that."
Student # 5 "It is required by the type of math question"

Question # 12 (Assignments) What portion of your homework do you manage to complete?
Student # 1 "All of it (with rare occurrences of being incomplete)"
Student # 2 "In class, when the teacher gives us class time I complete all of it."
Student # 3 "The easy questions if not all."
Student # 4 "all of it – 100%"
Student # 5 " 100% - 90%"

Question # 13 (Assignments) What portion of your completed homework is usually correct?
Student # 1 "80%, 90%"
Student # 2 "mostly all of it"
Student # 3 "more than 75% of it"
Student # 4 "mostly all of it – 9/10ths – 90%"
Student # 5 "100% - 80%"

Question # 14 (Assignments) How much time do you take to do your math homework?
Student # 1 "30 min – 1 hour"
Student # 2 "the amount of time our teacher gives us during class."
Student # 3 "15 minutes to 35 minutes"
Student # 4 "about 20 – 30 minutes."
Student # 5 "Depending, no more than 20 minutes"

Question # 15 (Tesy/Quiz) When you write a math test or quiz, do you usually manage to complete it? Why? Or Why not?
Student # 1 "Yes because I usually know the information, skip a question I do not know, etc."
Student # 2 "Yes because I understand math easily & it doesn't take me long to answer the questions."
Student # 3 "Yes, because most of the time I'm prepared for it and know it"
Student # 4 "I usually don't mange to complete it for our teacher makes the tests too long for everyone."
Student # 5 "Yes, because the teacher gives equal # of questions to time needed to complete"

Question # 16 (Test/ Quiz) What portion of your math test or quiz is usually correct?
Student # 1 "80 – 100%"
Student # 2 "mostly all of it"
Student # 3 "Between 70% and 95%"
Student # 4 "about 80% of it (4/5ths)"
Student # 5 "90% - 70%"

Question # 17 (Calculation Preference) Do you prefer to work out your math problem in your head or by using a pen/pencil and a piece of paper or by using your calculator? Explain why?
Student # 1 "My head if possible since it is more convenient to calculate things when lacking a pen/pencil and a calculator. Stimulates the mind more."
Student # 2 "I prefer using a pen/pencil & a piece of paper, because that way I know my answer is accurate."
Student # 3 "Using calculator because it's the easiest and it's efficient (unless you type wrong numbers)."
Student # 4 "I like to use a pen & paper, for then I can keep track of my work and look at the question."
Student # 5 "I try to do it in my head most of the time to get better at mental math but if it is a difficult question or % than I use a calculator."