THE USE OF THE ELECTRONIC SPREADSHEET AS A TOOL FOR
SOLVING WORD PROBLEMS

by

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B.A. York University, 1983

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The Electronic Spreadsheet as a Tool for

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ABSTRACT

The purpose of this study was to investigate the effect of using an electronic spreadsheet on the performance and problem-solving processes of Grade 10 students as they solve word problems.

Thirty students from an above-average mathematics class participated in the study. They were randomly divided into a spreadsheet (experimental) group and a computer-as-calculator (control) group. Both groups received hands-on training to become acquainted with the keyboard and the spreadsheet program. For the next six weeks, once a week for 75 minutes, the spreadsheet group solved word problems with the aid of the spreadsheet. The computer-as-calculator group solved the same word problems using pencil and paper, and the computer only as a calculator.

Data were collected from three sources: a posttest, a think-aloud interview, and a questionnaire. The posttest consisted of ten word problems. There was no significant difference between the two groups in the number of correct solutions to the problems. In the think-aloud interview students had to verbalize their thoughts as they solved six word problems. Students using the spreadsheet
displayed more problem-solving strategies and processes than students in the computer-as-calculator group (spreadsheet: n = 11, 778 processes, mean = 71.1; comp-as-calc: n = 9, 443 processes, mean = 49.2). The spreadsheet group also used specific strategies and processes more frequently: drawing a table or diagram (sprd = 48; comp = 19), decomposing the problem into subproblems (sprd = 109; comp = 67), trial and error (sprd = 49; comp = 5), estimation and successive approximation (sprd = 44; comp = 2). Students were also marked for the correct solutions of the six problems and the performance of the spreadsheet group was significantly better than the computer-as-calculator group ($X_{sprd} = 4.93; X_{comp} = 3.08$, $F = 9.45$, df = 1,26, $p < 0.01$).

Finally, students answered a questionnaire to determine their attitude toward using the spreadsheet and the computer-as-calculator to solve word problems. Students using the spreadsheet found it very helpful and fun whereas students in the computer-as-calculator group were mostly indifferent.
שבדת זאדה ממוקשת קחורין היכדה ושלה לרד
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CHAPTER 1

INTRODUCTION

Computers and Problem Solving

The Use of Computers in Schools

The decade of the 1980's will most probably be marked in the history of education as the time when computers entered and affected each classroom, from kindergarten to grade 12. Although computers are not changing the face of education, they are influencing the way curriculum is being taught and the role of the teacher in the classroom (Billings, 1983; Fey, 1984).

Shortly after the first microcomputer became available and affordable in the late 1970's, educators began to realize the potential of this tool in almost any educational setting. However, opinions as to how to implement this new electronic device varied. Implementation appears to depend very much on who is being asked, where their interest lies, and which philosophy of education they hold true.
In the course of events and debate of the last few years four main uses for the microcomputer in schools have emerged:

**Programming.** At the junior-secondary level learning to program a computer has become a subject very much like History, Geography, or Mathematics. Students in the computer science class learn to program a computer using such computer languages as BASIC and Pascal. At the elementary-intermediate level, programming languages such as Logo and Comol are used for introduction to programming.

**Computer-aided Instruction (CAI).** CAI is mainly associated with drill and practice, tutorials and games. The potential of its use lies with training of very specific skills. Schwartz (1983) makes the distinction between training and education: "In training, there need not be an explicit or implicit obligation for the learner to learn the underlying intellectual structure of what is being taught and learned" (p. 61). CAI software, by nature of its scope, is mainly product oriented, highly structured and it demands convergent thinking without the demand to understand underlying concepts or ideas. However, there is a need for students to be trained at certain
skills in various subjects and this is fulfilled with the use of CAI software.

**Simulations and Microworlds.** Simulations and microworlds are exploration-based learning. Students learn "powerful ideas" (Papert, 1980, p. 135) by manipulating and experimenting in a specific environment. The main features of a microworld are that it is (a) safe, (b) open-ended, (c) optimally structured, (d) exploration based and (e) learning as a process.

**Computer as a Tool.** Application programs such as spreadsheets, word processors, data base managers, graphics and other "tool" software can be used in all subject areas at all levels. The purpose of the tool is to empower the student and let him or her concentrate on the task rather than on the technical aspects of the task. For example, a word processor allows the student to concentrate on the actual writing process by enabling the student to make corrections easily and move the text around. A spreadsheet, for example, lets the user explore the world of numbers. Students do not need to do tedious computations. They can easily explore how the different components of a problem affect each other by changing formulas or numbers in different cells. When
using computer tools the user is not constrained by right or wrong in terms of what can be done on the screen. The user can explore various alternatives in an environment that is safe, open ended and optimally structured thereby enhancing divergent thinking and the process of learning.

Thus, when used as a tool, the computer becomes an "extension of the mind" (Turkle, 1984, p. 14) and it allows the student to explore in ways he or she cannot explore outside of the computer environment. Full advantage is taken of the features the computer has to offer.

**Problem Solving and Mathematics**

In the National Council of Teachers of Mathematics 1980 Yearbook, Stephen Krulik (1980), the editor, states that "As we enter the eighties, the theme [in mathematics education] appears to be 'problem solving'" (p. XIV). Osborne and Kasten (1980) confirm that direction by stating that "Problem solving is the primary focus of NCTM's curriculum recommendations for the decade of the eighties" (p. 51). Undoubtedly, a great deal of time, resources and attention have been directed towards research, teaching, and application of problem solving in the
mathematics curriculum since the beginning of the eighties.

All this interest in problem solving might prompt the following question: "Why should the emphasis in the curriculum of the eighties be problem solving?". Perhaps an additional question should arise "Does the integration of computers into everyday life have anything to do with the need to focus on problem solving in the curriculum?". Flake, McClintock and Turner (1985) help us understand the relationship between problem solving and computers:

In general, problem solving is likely to become more central to education as society becomes more complex. Advanced technology require sophisticated problem solving; at the same time, it provides the tools for more sophisticated problem solving. The rapid alteration in today's world suggest that the form and the goals of education are changing. Certain skills that used to be drilled for considerable periods are now replaced by an inexpensive calculator. Certain facts may be called forth when needed from a computer database rather than being memorized. In modern society, knowledge of facts, formulae, and specific solutions can soon become obsolete. Knowledge of how to approach and solve new problems, on the other hand, always will be applicable. Learning how to learn may become the focus of educational programs designed for changing societal needs. Problem solving is a way of learning that is not going to become obsolete. (p.103).
Musser & Shaughnessy (1980) believe the mathematics curriculum should become more strategy based and less content based:

Although much of mathematics is indeed devoted to the development of efficient algorithms to solve problems, the emphasis in this electronic age should be not on performing algorithms in a rote manner, but on developing and using algorithms to solve problems (p. 136).

Brown (1983) contends that there is a need for fundamental shift from formal textbook learning to informal learning-by-doing. The change will have an increased emphasis on domain independent skills (e.g., problem solving and information browsing) in conjunction with metacognitive skills (skills that have to do with learning how to learn, e.g., learning from one's errors) (p. 42).

An increased emphasis on problem solving all across the curriculum is undoubtedly important and a priority to educators. However, since there are certain intrinsic qualities in mathematics in relation to the problem solving process (Polya, 1980), it is plausible to put more emphasis on problem solving as part of the mathematics curriculum in particular. Branca (1980) cites other researchers who claim that mathematics is primarily a problem solving endeavor, a vehicle for generating and exercising problem solving,
and that problem solving is at the heart of all mathematics. As Polya (1981) states:

In mathematics, know-how is much more important than mere possession of information. What is know-how in mathematics? The ability to solve problems. (p.xii)

Mathematics, therefore, because of its intrinsic qualities, can be the leading subject area in the school curriculum which emphasizes problem solving.

Mathematical Problem Solving and the Spreadsheet.

This study explored the use of computers as tools in schools. The study focused on one particular tool, the electronic spreadsheet, and it explored how the electronic spreadsheet might affect the problem solving strategies and ability of Grade 10 students when they solve various algebraic word problems.

Rationale

The rationale for this study was partly based on Lesh (1985b) and Wilson's (1985) work with students who were using computer driven "conceptual amplifiers" (Lesh, p.7), such as the spreadsheets, to solve problems. It was also based on the realization that the electronic spreadsheet may be a powerful tool which can enable the student to:
a) Have a visual representation of the problem. A visual representation enables the student to explore relationships between various variables in addition to making the word problem a more concrete entity.

b) Use heuristic processes such as dividing the problem into subproblems, create tables, use trial and error, estimation, and successive approximation.

c) Calculate and manipulate different combinations of cells, thus freeing the student from static calculations that are involved in solving word problems. In turn, the exploratory and manipulatory freedom in use of the spreadsheet will enable the student to concentrate on both the heuristics and the processes involved in solving the word problems.

d) Approach problem solving in a new and perhaps more motivating and fun fashion.

According to Lesh (1985b), the capabilities of the spreadsheet can "...minimize the amount of time students spend on 'procedure doing' so that attention could be focused on the systems of relationships that
constitute the underlying conceptualization [of problem solving]" (p. 6). The statement above supports Kelman (1983) and Wilson’s (1985) claim that tools such as the electronic spreadsheet can free the student to concentrate on the heuristic processes rather than the product while engaged in problem solving.

Purpose of the Study

The following research questions formed the basis of this study:

1) Do students using a spreadsheet solve more problems correctly than students using the computer-as-calculator?

2) Do students using a spreadsheet employ overall more problem solving processes than students using the computer-as-calculator?

3) Do students using a spreadsheet employ more of any specific kind of problem solving processes than students using the computer-as-calculator?

4) Do students using a spreadsheet employ different problem solving processes in their approach to the
problems than students using the computer-as-calculator?

To answer the research questions it was necessary to use the think-aloud technique of data collection. The think-aloud approach has been used successfully in studies which investigated the problem solving process (Days, 1977; Duncker, 1945; Kilpatrick, 1967; Wheatley, 1980). Using this technique, the student thinks aloud as she or he is solving a problem. The students' comments are audio tape recorded so they may be later transcribed and analyzed. A fixed coding form enables the researcher to determine which processes take place and how often.

For the purpose of this study, the researcher created a modified coding form based on the works of Blake (1976), Kilpatrick (1967), Lucas et al. (1982), and Wheatley (1980). Their work is based on Polya's (1957) model of problem solving. For the think-aloud interview, students had to solve six problems and think aloud as they were solving the problems. The tape recorded protocols were later transcribed and analyzed using the modified coding form (see Appendix F).
Importance of the Study

The emergence of new technology has brought about considerable enthusiasm from both students and educators. This enthusiasm, though, is based more on intuition than on research. Because the use of computers in schools is relatively new, very little research has been done to understand the effect of computers on learning.

The importance of this thesis is threefold:

1) It will add to the still limited body of research on the use of computers in education.

2) The use of the electronic spreadsheet offers a different and more concrete and dynamic way of solving word problems. This method may be more beneficial to some students who have difficulty with traditional methods of solving word problems.

3) The electronic spreadsheet has practical uses both at home and in the workplace. Students who learn to solve problems on the spreadsheet will most likely be able to use this skill at their jobs and at home. Few people use the mathematics they learn in school at their jobs or at home. Mathematics should be used more and more often in everyday life.
Learning to solve problems on the spreadsheet brings the students closer to that goal.

Limitations Of The Study

The limitations of this study are imposed by the subjects, and the absence of a pretest measurement.

Subjects. All students who participated in this study were from the same mathematics class and were of above average ability. Therefore, the results of this study can only be generalized to a population with an above average ability.

Absence of pretest. Students were not administered a pretest. A pretest in this study could have given a better indication of students' abilities before the study, thus validating further the results.

Organization Of The Thesis

The first part of Chapter 2 contains a review of the literature on problem solving and, in particular, mathematical problem solving. The second part of Chapter 2 consists of a review of the different ways the computer can be used for mathematical problem solving.
The methodology of this study is described in Chapter 3, including a description of the students, the treatment and the data collection method. Chapter 4 is the results section which contain data from the posttest, the think-aloud interview and the questionnaire. Chapter 5 contain the discussion and conclusions of this study.
CHAPTER 2

REVIEW OF THE LITERATURE

This review of the literature is divided into two parts. Part one is a review of the literature on mathematical problem solving. Part two is a review of the literature on the use of computers in mathematical problem solving.

Since the literature on problem solving is so vast, only aspects that pertain to the present thesis are discussed. These aspects are Polya's model of heuristic problem solving and its relationship to learning and research.

Contrary to the vast research literature on problem solving, research on the use of computers in mathematics education is very limited. This is probably due to the relatively short time since microcomputers have been introduced into the educational system. Most of the literature that is available though is based on personal accounts and ideas of people who have been involved implementing computers in the schools. Nevertheless, some 'serious' research has been taking place and each year more is available.
The Origins of Problem Solving in Modern Education

The importance of problem solving to modern education was first recognized and written about by such scholars as Dewey (1933), Duncker (1945) and Polya (1957). Although all three had a great influence on the direction of problem solving research and application, Polya remains the main philosophical and practical influence in the field of problem solving (Kulm, 1982; McClintock, 1982). Other scholars, teachers and researchers such as Kilpatrick (1967), Wickelgren (1974), Krutetskii (1976) have further helped to understand the complexity of what constitutes 'problem solving'.

To these educators and others the term "problem solving" has no one uniform meaning. The following two definitions reflect a common thread to most definitions. For Polya (1980), problem solving takes place "...if we have to search for the means, reflecting consciously how to attain the end. It is to find a way where no way is known off hand, to find a way out of difficulty, to find a way around an obstacle..." (p. 1). Mayer (1985) defines it as follows:

A problem occurs when you are confronted with a given situation, let's call that a given
state — and you want a different situation — let’s call that the goal state — but there is no obvious way of accomplishing your goal. Problem solving refers to the process of moving from the given state to the goal state of the problem. (pp. 123-124)

Branca (1980) understands that problem solving can be a goal, a process or a basic skill. Problem solving as a goal is independent of specific problems, procedures, methods and mathematical content. Problem solving as a process is perhaps best understood as the heuristic processes (see Figure 1 for definitions of heuristics) that students use to solve problems. Problem solving as a basic skill concentrates on specifics of problem content, problem types and solution methods.

Although there is a distinct difference between the three concepts of problem solving, Polya’s Four Steps to Problem Solving and the heuristics involved in each step is a common thread which runs through all of them, regardless of how problem solving is understood to be.
Modern heuristic endeavors to understand the process of solving problems, especially the mental operations typically useful in this process. (Polya, pp. 129-130).

I wish to call heuristics the study...of means and methods of problem solving...I am trying...to entice the reader to do problems and to think about the means and methods he uses in doing them. (Polya, 1962, p.VI).

An heuristic is any device, technique, rule of thumb, etc. that improves problem solving performance. (Kilpatrick, 1967, p. 19).

Heuristics may be described as rules for selecting search paths through a problem space. The theory of problem solving is concerned with systems of heuristics or methods of search which will exploit the information in the task environment (Kantowski, 1974, p. 7).

A general suggestion or strategy, independent of any particular topic or subject matter, that help problem solvers approach and understand a problem and efficiently marshall their resources to solve it. (Schoenfeld, 1980, p. 9).

Heuristics are general procedures or hints which help one discover or develop a plan for solving a problem. This characterization make it appear that heuristic processes are independent of a particular problem being solved. (Kulm, p. 19).

Figure 1. Some definitions and descriptions of heuristics (from McClintock, p. 172).
Heuristic Processes.

When looking at problem solving as a process the emphasis is put on the type of strategies and heuristics a learner uses. By recognizing and being aware of the heuristics used, the problem solver is able to "...approach and understand a problem and efficiently marshal their resources to solve it" (Schoenfeld, 1980, p. 9). Although different problems and situations require a combination of different sets of heuristics, it is widely accepted that Polya's model of heuristics covers most heuristics needed for mathematical problem solving.

---

1. Understanding the problem.

   a) What is the unknown?
   b) Draw a figure
   c) Introduce suitable notation
   d) Separate the various parts of the condition.

2. Devising a plan.

   a) Do you know a related problem?
   b) Could you solve part of the problem?
   c) Did you use all the data?

3. Carrying out the plan.

   a) Check each step
   b) Can you see clearly that the step is correct
   c) Can you prove that it is correct?

4. Looking back.

   a) Can you check the result?
   b) Can you derive the result differently

---

Figure 2. Polya's four steps of problem solving
To be a successful problem solver, the student has to use these four general heuristics. Each step carries within it more specific heuristics in the form of questions. Figure 1 describes the four steps and some of the specific heuristics in each category as suggested by Polya. In all Polya asks 36 questions under the four headings. Most of the actual problem solving processes in Polya's model take place in the first 2 general heuristics. However, there is continuous interaction between all heuristics. A student may use certain processes to understand the problem and then devise a plan and then carry out the plan. In carrying the plan s/he may recognize a mistake and return for revision to step one or two. This interaction between the four steps continues until the problem is solved.

By concentrating on the strategies and heuristic processes, problem solvers are not restricted to knowing how to solve only specific types of problems. Rather, the heuristics advocated by Polya are universal and do not limit the problem solver to specific types of problems. That problem solving process is the ability to utilize those heuristics which Polya and others describe.
Learning Heuristics.

The process of learning to problem-solve is long, complex and demanding. It is a continuous process, a result "...of a combination of carefully planned instruction [on behalf of the teacher] and experience [on behalf of the students] in solving a variety of problems" (Kantowski, 1980, p. 196). Understanding and being clear about the goals of what a teacher wants to present to his/her students is highly important when teaching problem solving (Kilpatrick, 1985).

The main goal when teaching students problem solving is to give them tools to tackle any problem which might confront them, even if it is an unfamiliar problem in an unfamiliar situation and format. The first kind of exposure to these tools are the general heuristics which students learn, unrelated to specific problems, procedures or mathematical content. McClintock (1982) quotes Henderson and Pingray (1953):

Unless students study the process of solving problems as an end in itself there is a scant likelihood that they will learn the generalization which will enable them to transfer their ability to solve problems to new problems as they arise.

This means that if students are able to approach a problem by saying to themselves that they must
understand the problem, then devise a plan, carry it out and look back, regardless of the problem, then they have learned problem solving as an end in itself.

Wickelgren (1974) claims that knowing problem solving as a goal is what he calls "...knowing general problem solving methods" (p. 4). These 'general problem solving methods' "serve to guide the student to recognize what relevant background information needs to be understood" (p. 4) in order to solve problems regardless of their content or specific heuristics that need to be used.

Learning general heuristics as a goal in itself is not nearly enough for students to become competent problem solvers. Although there are various methods of teaching problem solving, two approaches are most commonly known:

1) The top-down approach
2) The bottom-up approach.

The Top-Down Approach.

The top-down approach concentrates on training students in heuristic techniques of wide applicability (Kilpatrick, 1985). In this approach students are considered innately good problem solvers. The role of
the teacher is to provide opportunities and environments whereby the student can practice his or her skills in problem solving (Papert, 1980). By environments Papert means placing children in mathematically rich and stimulating situations and allowing them to experiment and discover. There are other factors involved in this top down approach of learning problem solving. Students, notes Papert (1975) "...learn by doing and by thinking about what they do" (p. 219). When solving problems, it is necessary for students to reflect on each step as they are doing it (Schoenfeld, 1985). The problem solver needs to learn to reflect on his/her progress in problem solving and assess the effectiveness of the procedures being used (Kilpatrick, 1985). To help students reflect on what they are doing students are allowed to cooperate with each other and the role of the teacher is to become more of a facilitator.

The Bottom-Up Approach.

The bottom-up approach concentrates first on teaching individual processes using certain problem types. The teacher can choose problems which will reinforce the heuristics s/he is interested in promoting. By presenting the students with specific
problems which will promote desired heuristics
students are able to practice different strategies and
become proficient in them (Charles & Lester, 1982). At
the first stage, Charles and Lester propose a matched
approach. Using this approach, the students solve
problems which involve the same set of solution
strategies, such as dividing the problem into
subproblems and guessing and checking. Next they learn
to solve problems with different sets of solution
strategies, such as looking for a pattern and working
backwards. After learning to solve problems with
different sets of solution strategies, students are
given nonmatched set of problems. Here problems are
mixed by solution strategies which develops students'
abilities to select a particular solution strategies
from a set of possible solution strategies. By
teaching students to solve particular problems using a
distinct set of heuristics, students can become more
efficient problem solvers (Mayer, 1985). Using this
approach students need to recognize the conditions
under which a strategy can be used effectively as well
as having to select a particular strategy from two or
more alternatives (Lester, 1985).
Research and Problem Solving Heuristics

In the past, standardized tests have been widely used to measure problem solving ability. However, the emphasis in problem solving research has been and is shifting to the study of the processes used to arrive at the answer (Kulm, 1982). This shift started with the work of Duncker (1945) which was followed by Kilpatrick (1967). The aim of Kilpatrick's study was to develop a system for analyzing the processes students use to solve word problems. Students were asked to think aloud as they solved the various word problems and their tape-recorded protocols from the interview were coded by means of a system based on the heuristic processes identified by Polya in How to Solve It (Kilpatrick, 1967). Webb (1975), Kantowski (1975), Blake (1976), Days (1977) and others followed Kilpatrick in studying problem solving processes using the think-aloud method of investigation. In the above studies a relationship was sought between an independent variable such as the content of a problem or its syntax structure and the type and number of processes used by the subjects. By looking at the heuristic processes students use when solving problems, it is possible to take a closer and deeper look at the relationships between the independent and
dependent variables and as a result have a better understanding of the problem solving process. For example, Duncker (1945) considers the heuristic method of reasoning to be fundamentally that of replacing a problem goal with a series of subgoals. In order to have a deeper understanding of this particular process of dividing the goal into subgoals, it is necessary to understand the heuristics involved in such a process. These heuristics were obtained through the think-aloud method of investigation.

Variables Which Affect Problem Solving Processes

There are a number of variables which can affect the problem solving process. Kilpatrick (1975) divides them into three groups: subject, task and situation. Research on problem solving revolves around these three variables and their subcategories. Changes in any of these variables may result in changes in product and processes used by the problem solver. The following is a description of the variables involved in mathematical problem solving research taken mainly from Kilpatrick's Categories of Problem Solving Research Variables:

Subject Variables. Subject variables are those quantities which describe or measure specific
attributes of the problem solver. Charles and Lester (1982) divide the subject variable into three factors which affect problem solving. Cognitive factors which include memory, analytical ability, reading ability and spatial ability, Experience factors which include previous math background, age, and familiarity with solution strategies, Affective factors such as interest, motivation, anxiety stress. All these factors have direct effect on problem solving performance.

Task Variables. Task variables are those variables which relate to the actual problem. Task variables can be divided into five categories. Content factors describe the mathematical information in the problem statement, with reference to the meaning of terms and phrases. Context factors describe nonmathematical information including the verbal context or setting, and the information format (Goldin, 1985). Structure factors are intended to describe the intrinsic mathematical structure of a problem or as Lester (1985) put it: "Structure variables describe the mathematical (logical) relationships among the elements of a task (p. 62). Syntax factors are those involving the relationship among, as well as the arrangement of, words and
symbols in the statement of a task. Format factors describe the different manners or settings in which a problem may be presented, for example, whether the problem was on a computer screen, on a piece of paper, or whether or not the student was asked to think aloud during problem solving.

**Situation Variables.** Situation variables describe the physical and psychological environment in which the problem solving event takes place. Physical setting describes the type of space (e.g., classroom, laboratory) and nature of space (e.g., familiar, comfortable) in which the problem solving takes place. Psychological factors describe the purpose of the event, type of procedure used (e.g., evaluative, diagnostic) and the nature of the learning environment (e.g., type and amount of feedback).

The variables mentioned above are the independent variables which have a direct effect on the dependent variables which include product and process variables.

**Product.** Product variables concern achievement of the solution to the problem. They relate mainly to the correctness or incorrectness and completeness of the solution.
**Process.** Process variables are derived mainly from a students’ verbal report (think aloud) during problem solving and/or from his or her written work. From the process variables one can learn which type of heuristics were used, how many and in which order, enabling the researcher to get a closer look at the relationship between one or a number of the independent variables and the type and number of processes used.

**Computers in Mathematics and Problem Solving Education**

Since the introduction of calculators and computers into the education system, some educators have questioned "the content and emphasis in school mathematics programs" (Fey & Heid, 1984, p. 21). Traditionally and currently much emphasis is put on procedures for transforming algebraic expressions and solving equations and inequalities. Instructional time is devoted mainly to manipulative skills and computation, leaving very little time to concentrate on the actual process of problem solving (Fey, 1984). Computation and transformation skills are important and can be good mental exercises, however, they contribute little to the understanding of the problem solving process.
The use of calculators in mathematics education can relieve students from some of the computations needed to solve problems. But the use of the computer can do more than just help students with their computations, it can "...create environments in which people can be given the opportunity to think mathematically and solve challenging problems" (Silver, 1985, p.263). In addition to being able to provide a 'mathematically rich environment', the computer is also an extremely motivating tool which draws and captivates students (Hatfield, 1984; Fey, 1984; Malone, 1981; O'Shea & Self, 1982).

Problem Solving and the Computer

There are various ways by which the computer can be used to enhance mathematical problem solving and problem solving in general. The list below describes the different methods:

1) Programming
2) Computer Aided Instruction (CAI) which includes drill and practice and tutorial programs.
3) Simulations and microworlds
4) Tools
5) Games
6) Artificial Intelligence
Because the first 4 categories concern this thesis, the review focuses only on them.

**Programming**

Programming is widely used by many computer advocating educators to promote mathematical problem solving (Camp & Marchionini, 1984; Channell & Hirsch, 1984; Flake, McClintock & Turner, 1985; O'Shea & Self, 1982; Roberts & Moore, 1984; Wright & Forcier, 1986). Students faced with a problem or a goal which needs to be solved or reached by giving instructions to the computer have to utilize various problem solving processes. By utilizing these processes students can become better problem solvers.

There are many programming languages which are used in the schools with Logo, BASIC and Pascal most widely used. Logo is a structured language designed primarily for learning (Abelson & DiSessa, 1981; Watt, 1983). BASIC is an unstructured language which was designed as a general purpose language. Pascal is a structured language also designed as a general programming language.

**Logo.** Logo was created with the learner in mind. Learning, according to the philosophy upon which Logo is based, occurs through discovery and exploration of
Turtle Geometry is a mathematically rich environment which allows students to gain understanding of mathematical concepts by manipulating the turtle and the language which controls it. The turtle is a shape on the computer screen which can be controlled by the student. The turtle understands certain commands which are part of the Logo language, such as Forward, Back, Left, Right and many others. For example, a student can type Forward 100 and the turtle will immediately respond by moving on the screen forward 100 turtle steps.

According to Papert (1980), the turtle is an "object-to-think-with" (p. 11) which also makes it easier for the student to "think about their own thinking" (p.22), an important part of the process of problem solving according to the top-down approach to problem solving. Logo embodies in it many features or "powerful ideas" (pp. 135 - 137, Watt & Watt, 1986, p. 2) which can make certain mathematical concepts easy to understand. For example, the turtle is a powerful idea through which certain mathematical and geometrical concepts are better understood. Other powerful ideas in Logo which relate to problem solving as described by Watt & Watt (1986):
1) The use of procedures makes it necessary to divide a problem into smaller subproblems and create an interface (a connection) between the procedures. Making the connection requires a deductive process.

2) The use of variables which makes the concept of a variable better understood.

3) Debugging. "The process of finding, identifying and eliminating bugs is at the heart of any Logo learning experience" (p. 2). Correcting mistakes incorporates such processes as deductive reasoning, looking for a pattern, predicting and dividing a problem into subproblems.

4) Repeating, iteration and recursion incorporate such processes as looking for a pattern and understanding variables.

Other powerful ideas in Logo which are not connected to specific commands are:

1) There are various ways by which a goal can be reached, depending very much on the individual's programming and approach to the problem.

2) Creating mathematical theories. Logo's math rich environment allows students to make theories and try them out.
Goldenberg's (1985) (see Figure 3) example of how word problems can be solved via Logo programming is a classic example of Logo's use in mathematical problem solving. In the example, students have a number of possible ways of solving the problem. They have to use such heuristics as dividing the problem into subproblems, making a connection between the subproblems, estimating the possible solution, searching for a pattern and making deductions. In addition, the student is also learning the concept of a variable and is able to have a graphic representation of the problem using turtle graphics.
A hot air balloon makes a seven-day journey covering 2100 miles. Each day, the distance it travels is 50 miles greater than the distance it traveled during the previous day. How far did it travel the first day?

Process 1:

```
1 TO DAY.7
10 OUTPUT (50+DAY.6) OUTPUT (50+DAY.5) OUTPUT (50+DAY.4)
11 END
1 TO DAY.6
10 OUTPUT (50+DAY.5) OUTPUT (50+DAY.4) OUTPUT (50+DAY.3)
11 END
1 TO DAY.5
10 OUTPUT (50+DAY.4) OUTPUT (50+DAY.3) OUTPUT (50+DAY.2)
11 END
1 TO DAY.4
10 OUTPUT (50+DAY.3) OUTPUT (50+DAY.2) OUTPUT (50+DAY.1)
11 END
1 TO DAY.3
10 OUTPUT (50+DAY.2) OUTPUT (50+DAY.1) OUTPUT (50+DAY.0)
11 END
1 TO DAY.2
10 OUTPUT (50+DAY.1) OUTPUT (50+DAY.0) OUTPUT (50+DAY.2)
11 END
1 TO DAY.1
10 OUTPUT GUESS OP 150
11 END
1 TO TOTAL.TRI
10 OUTPUT (DAY.1+DAY.2+DAY.3+DAY.4+DAY.5+DAY.6+DAY.7)
11 END
```

Process 2:

```
1 TO DAY.7
10 OUTPUT (50+DAY.6) OUTPUT (50+DAY.5) OUTPUT (50+DAY.4)
11 END
1 TO DAY.6
10 OUTPUT (50+DAY.5) OUTPUT (50+DAY.4) OUTPUT (50+DAY.3)
11 END
1 TO DAY.5
10 OUTPUT (50+DAY.4) OUTPUT (50+DAY.3) OUTPUT (50+DAY.2)
11 END
1 TO DAY.4
10 OUTPUT (50+DAY.3) OUTPUT (50+DAY.2) OUTPUT (50+DAY.1)
11 END
1 TO DAY.3
10 OUTPUT (50+DAY.2) OUTPUT (50+DAY.1) OUTPUT (50+DAY.0)
11 END
1 TO DAY.2
10 OUTPUT (50+DAY.1) OUTPUT (50+DAY.0) OUTPUT (50+DAY.2)
11 END
1 TO DAY.1
10 OUTPUT (50+DAY.0) OUTPUT (50+DAY.1) OUTPUT (50+DAY.2)
11 END
1 TO TOTAL.TRI
10 OUTPUT (DAY.1+DAY.2+DAY.3+DAY.4+DAY.5+DAY.6+DAY.7)
11 END
```

Figure 3. Two methods of solving a problem with Logo
BASIC, Pascal and other languages. Although not designed for learning with the learner in mind, programming in BASIC, Pascal and other languages can also be powerful languages to learn with. Despite the flaws of the BASIC language and the limitations of Pascal, both languages are widely used in schools and can promote mathematical problem solving.

Camp & Marchionini (1984) suggest ten ways students can learn problem solving through programming using any of the above languages:

1) Run a program and discuss the results.
2) Simulate the execution of a program.
3) Annotate a program to explain its features.
4) Complete a program by inserting key instructions.
5) Predict the output.
6) Modify the program to perform a related task.
7) Make an inference from an error message.
8) Find structural errors in a program and correct them.
9) Compare programs regarding their procedures, efficiency, and output.
10) Write and run a program.
Tickets to a baseball game are $0.75 for students and $1.25 for adults. If 195 tickets were sold, producing receipts of $201.25, how many of each type were sold?

```
110 PRINT "ENTER A NUMBER FOR YOUR GUESS ON THE NUMBER OF STUDENT TICKETS SOLD"
120 A = 195 - N
130 S = .75 * N
140 P = 1.25 * A
150 T = S + P
151 PRINT "STUDENT", N, S
152 PRINT "ADULT", A, P
153 PRINT "TOTAL", 195, T
160 IF T = 201.25 THEN 90
170 PRINT "GUESS AGAIN"
180 GOTO 10
190 PRINT "THAT'S CORRECT"
100 END
```

Figure 4 - A method of solving a word problem using BASIC
In Figure 4 Smith (1984) illustrates a program which the student has to program and run. He or she needs to use such heuristics as trial and error, estimation, and deduction to solve this problem. They can also modify the program to solve a similar problem with a different twist.

**Computer-aided Instruction**

The use of computer aided instruction (drill and practice and tutorials) to supplement mathematics instruction and promote problem solving skills can be effective if a program is well designed (Nolan, 1984; Olds, 1985; Silver, 1985). CAI programs can help students become better problem solvers for a number of reasons:

a) They can do the tedious task of computation.

b) They can have very good visual representations of a problem, which can include graphics and diagrams.

c) They can give feedback.

d) CAI in a games framework can be highly motivating.

e) It can tutor for specific skills at an individualized pace with infinite patience.
In addition, CAI is highly structured and sequential which can make it beneficial for students who need more structure in their learning.

Despite the advantages of CAI there are some serious criticisms of the CAI approach to learning. According to Papert (1980), Schwartz (1983) and Olds (1985) there are some hidden aspects of the CAI approach to education which makes it unattractive to many educators. These hidden aspects listed below indicate that although CAI can be effective in promoting problem solving skills under certain conditions, it is important to acknowledge the limitations and disadvantages that come along with it.

a) The computer is in control of the learner instead of vice versa. To learn, the student must suspend all normal forms of interaction and engage only in those called for by the program.

b) Learning involves understanding how the program expects the learner needs to behave. The learner needs to conform and adapt to the program demands.

c) Learning is linear, a step by step process. In learning from the computer, the student must suspend creative insight, exploration, intuitions and other nonlinear mental phenomena (Olds, 1985).
Simulations and Microworlds

Although simulations and microworlds are different in definition (see Figure 5) both environments have similar qualities which make them 'fertile ground' for problem solving. Microworlds and simulations are exploration-based, optimally structured, safe and open-ended. Students can explore and experiment, guess and estimate and enjoy the dynamic nature of the environment. The student is in full control of the program and is free to make decisions she or he sees to be right. Whatever the decision the student makes, the consequence of that decision is displayed on the screen. From the feedback the student gets, further theorizing and experimentation can take place. From manipulating the environment certain problem solving strategies are learned. For example, in The Incredible Laboratory by Sunburst each student is placed in the role of a scientist creating monsters in a laboratory. By selecting from a list of chemicals a monster is created with six different features. The student must determine which chemical was used to create each part. By doing this the student needs to use various problem solving strategies such as information gathering, looking for a pattern or sequence, analyzing and successive
Simulation

Simulation software is interactive software that models a real situation in such a way that the learner is able to explore the relationships among various parameters of the simulation by making decisions and observing the consequences of these decisions (Flake, McClintock and Turner, 1985, p. 393).

Microworld

Microworlds are small learning environments which are fun for learners to use and have important skills and powerful concepts embedded in them (Watt, 1983, p. 7).

Microworlds encompass objects and processes that we can get to know and understand. The appropriation of the knowledge embodied in those experiences is made possible because the microworld does not focus on problems to be done but on neat phenomena that are inherently interesting to observe and interact with (Lawler, 1983, p. 139).

Figure 5. Some definitions of simulations and microworlds.
scanning. The Incredible Laboratory is designed primarily to promote problem solving strategies.

A different kind of simulation is Rocky's Boots from The Learning Company. In Rocky's Boots, students learn specific content and concepts in electricity through problem solving in an open ended, exploration based environment.

Tools

Primarily, computer application programs are like any other tool. They can help the individual do tasks faster and more accurately. Computer tools, however, can be more than just physical tools which allow the individual using it to become more accurate or efficient, they can be mind amplifiers or as Turkle (1984) put it they can be "...an extension of the mind" (p. 14). Olds (1985) is more specific on the power of the computer as a tool by stating that "Learning is a human activity that can be significantly enhanced through the use of powerful tool programs on the computer" (p. 12). A tool also allows the learner to:

a) Look and study a problem from many other perspectives.
b) Evaluate several possible alternative solutions to a problem and decide on the best one.
c) Change his or her mind in light of new information or an altered perspective.

There are various computer tools with different applications such as word processors and data base managers. There are also various 'numbers' tools which can be be used to enhance computational skills and mathematical problem solving such as TK! Solver and muMath (Fey & Heid, 1984). Since the purpose of this study is to determine the usefulness of the spreadsheet in solving word problems, this section will focus on the use of spreadsheet as a tool in solving word problems.

A spreadsheet is a dynamic, electronic matrix consisting of C columns times R rows of cells. Each cell has a value rule specifying how its value is to be determined. Every time a value is changed in one of the cells, other cells linked to it by a value rule will change accordingly. Although seemingly simple, the spreadsheet is a powerful tool which can be utilized for various uses. Its visual format and ability to implement 'What If?' questions in an interactive manner makes it a powerful tool for economic modeling, business forecasting and other
applications. In mathematics education the spreadsheet could also be used for various applications. For example, algorithms that are recursive, iterative or suitable for tabular format can be implemented on the spreadsheet. Word problems can be set up, analyzed and solved on the spreadsheet. It can also be used for teaching mathematical modeling and problem solving as well as for the study and implementation of algorithms (Arganbright, 1984).

There are some features which are unique to the spreadsheet and which make it particularly powerful for mathematical problem solving. One of those features is that the problem is represented visually. According to Kay (1984) "The visual metaphor amplifies one's recognition of situations and strategies" (p. 57). The power of the visual representation of the problem is multiplied especially when the representation is dynamic. A change in one cell creates changes in all related cells allowing the student to witness how all cells are connected and interrelated. This allows a better understanding of how the different components of the problem are interlinked and affect each other.

A second feature unique to the spreadsheet is that it requires the student to create tables and
divide the problem into subproblems. Both of these heuristics are considered extremely important. For example, Flake, McClintock and Turner (1985) state that "A crucial aspect of problem solving involves breaking down the problem into a series of subproblems" (p. 95). A student solving a word problem with the aid of the spreadsheet needs to break the problem into subproblems and fit each part into a different cell. In addition, he or she also has to be able to create a connection (or interface) between the cells or the different parts of the problem and this necessitates deductive reasoning. The heuristic that is linked with dividing the problem into subproblems is constructing a table. Osborne & Kasten's (1980) summary report on NCTM's PRISM project shows that six of the eight sample groups interviewed for the study thought that 'constructing a table and searching for a pattern' is the most important heuristic that should be taught to elementary and secondary school students. For a student to solve a problem on the spreadsheet, s/he must put the problem in a certain format. That format is usually a table or table-like format.

A third feature which is unique to spreadsheets is the use of trial and error and estimation processes. Both heuristic processes are recognized as
important to the problem solving process (Musser & Shaughnessy, 1980; Reys et al., 1982; Schoen et al., 1983). To solve a problem using the spreadsheet, the student needs to use trial and error and estimation heuristics. Students seldom use trial & error, estimation and successive approximation when solving equations. However, when using the spreadsheet to solve problems these processes become part of the exploration and experimentation. Students are encouraged to estimate. If the result is not what the student expected, s/he can try a different value without having to do tedious recalculations.

Exploration is possible and part of the learning process. It is possible to enter different numbers in certain cells and see the outcome. It is also possible to change value rules in different cells and see how that might affect the other parts of the problem as well as the solution. Students learn to understand the concept of a variable in a concrete fashion making it easier to understand how a change in the value of a variable affects the solution and other parts of the problem.

In conclusion, the dynamic nature of the spreadsheet as well as the facility with which it is possible to explore and experiment makes this a
tool with which students may be able to solve word problems. The potential of the spreadsheet as an effective computer tool in facilitating students' solving algebraic word problems was put to test in the present thesis research. The topic of investigation, namely, the use of the electronic spreadsheet as a tool in solving word problems has, to the knowledge of the researcher, never been investigated before.
CHAPTER 3

METHODOLOGY

The purpose of this chapter is to describe the methodology of this study. A description of the students, the treatment and the data collection method are the main components of this chapter.

Research Design

The type of design used in this research is a 'Posttest-Only Control Group Design' (Borg & Gall, 1983, p. 670), and the steps involved are as follows:

1) Randomly assign subjects to the control and experimental groups.
2) Administer the tool to the experimental group but not to the control group. In the case of this study, the treatment refers to the use of the spreadsheet to solve word problems.
3) Administer the posttest and other forms of data collection methods to both groups.
The following is a description of the sequence of events as they occurred for this study:

1) The Mathematics department at Sutherland Secondary School in North Vancouver expressed their willingness to have this study take place with their Grade 10 Math Honours class. Mr. Terry Kremseter, the Grade 10 Math teacher, expressed his enthusiasm and the class chosen for the study was his.

2) The students, 30 in number, learned to use the Apple IIe keyboard and the AppleWorks spreadsheet in two periods, each of one hour and fifteen minutes.

3) The students were stratified by gender and then divided randomly into two groups, consisting of 15 students each. One group was designated as the spreadsheet group (experimental group) and the other designated as the computer-as-calculator group (control group). Each group had 8 female students and 7 male students. The assignment of students to each group was random and was done with the aid of the computer language Logo.
4) For the next six weeks, once a week for one period, the members of each group solved the same word problems. The spreadsheet group (experimental group) used the spreadsheet to solve the word problems whereas the computer-as-calculator group used the computer only for calculations.

5) At the end of the six weeks period both groups were administered an identical test which consisted of ten word problems.

6) Following the test, each student was interviewed individually for one period. The students had to solve six additional word problems. As they solved the word problems they had to think aloud. Their verbalizations were recorded on an audio tape and later transcribed and analyzed. After solving the six word problems each student was given a questionnaire to fill out.

Subjects

All the students who participated in the study came from the same Grade 10 Honours Math class at Sutherland Secondary School. The school is located in a mainly white middle class neighborhood. Most students were born and raised in that neighbourhood and
know each other from previous schools. The occupations of parents ranged widely from teachers and policemen to middle management positions and owners of small private businesses. The class consisted of 30 students in all, 14 boys and 16 girls. For a student to be enrolled in this particular Grade 10 Honours Math class she or he had to have either been recommended by their Grade 9 teacher for obtaining good marks or having special mathematical 'insight' or they had to have expressed their desire and commitment to be in the class.

The students in this class had to cover the same curriculum material as the other regular Grade 10 students and the content of their bimonthly unit tests did not differ considerably from the other regular Grade 10 bimonthly unit tests. The main difference between this class and the other Grade 10 Maths classes was in the degree of difficulty of their exercises in class, and the amount of homework they had to do.
General Procedures

Computer Familiarization

The computer room at Sutherland Secondary School contained 19 computers, 18 of which were Apple IIe's and one Apple II+. Since the spreadsheet program used in the study was the AppleWorks spreadsheet, only an Apple IIe with 128K and an eighty column card could be used. As a result only fifteen computers were suitable for the study.

Although only the experimental group was to use the spreadsheet for the purpose of this study, both groups were given instruction and hands-on experience using the spreadsheet program. Two 75-minute periods were needed to teach the different functions of the spreadsheet before the students could start to solve any word problems. If only half the class had received instruction on how to use the spreadsheet, the other half would have been in class working on their unit. This would have left the students learning to use the spreadsheet behind in terms of the material they had to cover in class. This was unacceptable to both the Principal and the Mathematics teacher to have half the
class miss two periods. In addition to the time factor, both the Principal and the Mathematics teacher recognized the value of the spreadsheet as a tool and expressed their wish that all members of the class learn to use the spreadsheet.

There were a number of advantages as well as disadvantages to having all the students learn to use the spreadsheet program. The main advantage of both groups learning to use the spreadsheet was that they also learned to use the keyboard. Since both groups were going to use the computer, and most students were not familiar with the keyboard in the first place, it was reasoned that through learning to use the spreadsheet the students would also learn to use the keyboard.

The most visible disadvantage to having the computer-as-calculator group learn to use the spreadsheet was the possibility that it might affect the manner in which they solved problems without the spreadsheet. However, it is difficult to determine the effect that the two training sessions had on the problem solving abilities of the students during the later stages of the study.
During the first session, students spent the first half hour learning about the various components of the computer, namely, the ROM and RAM, the disk drive, the monitor and the keyboard. The program used for this purpose was "Know Your Apple IIe". The students were then instructed on how to load the AppleWorks program. The routine was elaborate since each computer had only one disk drive. Having only one disk drive made the whole process of loading AppleWorks and data files more complex than if there were two disk drives. Following the loading procedure students were given Worksheet #1. Most students completed Worksheet #1 by the end of the first session. During the second session they were given Worksheet #2. Those who did not complete Worksheet #1 had to complete it first before moving on to Worksheet #2. Both worksheets had the same structure. Students had to perform tasks on the spreadsheet and write down the outcome of each task on the worksheet. The worksheets were handed in to the researcher at the end of each period.
The Treatment

For the treatment period, which lasted six weeks, both the experimental group and the control group came to the computer lab once a week for one period of one hour and fifteen minutes. The experimental group came on Mondays and the control group on Tuesdays. While one group was in the computer lab the other group was with their teacher working on curriculum related material. When working on word problems in the computer lab, students were allowed to work either by themselves, as some chose to do, or cooperate and share their ideas with others. Those who chose to share their ideas still had their own computer and worksheet for which they were accountable and responsible. Most students chose to work with others and only a few chose to work by themselves. When questioned by the researcher as to why they preferred working by themselves the most common response was because they could concentrate better when working alone.

When students had problems which they could not solve by themselves or with assistance from others, they were allowed to seek help from the researcher.
The following illustrates how assistance was facilitative:

S - I am having problems with question 5. I cannot understand what I am doing wrong.

R - You think you might be doing something wrong...

S - Yes, for $T$ (time) going back I put $3.5 - D113$ which is the time going there, and doesn't matter what I put for the variable which is the speed going I always get that the time going there and the time coming back added together is 3.5 hours.

R - Something isn't working right for you with $T$. Whatever number you put for your variable which is the speed going, the added value of $T1$ and $T2$ is always 3.5 hours.

S - Yeah, for my time going I put distance divided by rate and for my time coming back...

R - So for the time going you put distance divided by rate, and for the time coming back you put 3.5 minus whatever the time going...

S - So really if $T2$ is 3.5 minus $D113$ and then I add them up together, they will always be 3.5 right?

R - What do you think?

S - Yeah, I really have to make the time coming back distance coming back divided by speed coming back and than add $T1$ to $T2$ to get 3.5 hours...right...right that's what I'll do.
**Class Work During Research Period**

For the first two weeks of the study students in the class were solving linear equations and a variety of word problems with one variable. On the third and fourth week they started solving linear equations with two and three variables. Up to this point the type of problems done in class were similar to the problems they had solve in the study. On the fifth and sixth week a new unit in geometry was introduced to the class. The type of problems solved were different from the problems students had to solve for the study. During the seventh and eighth week the students were again introduced to a new unit, but this time the unit was on Consumer Maths and some of the word problems they had to solve in the study were again similar to the ones they were solving in class.

**The Word Problems**

For the duration of the treatment, which took six periods, students had to solve 42 word problems altogether. Each set of problems consisted of fifteen word problems, except for the last set which consisted of only twelve word problems. The rational for the
decision to have only twelve problems in the third and last set was because hardly any of the students completed all fifteen problems in the first two sets. The students had two periods in which they had to complete each set of word problems. Whether they completed the set or not at the end of the second period, they had to move onto the next set for the next two periods. This situation could have presented a problem if the type (see next section) of problems in the first, second, and third set were in exactly the same order. This was not the case, however. Thus in the event someone did not fully complete any of the sets, it did not result in his or her not solving certain types of problems.

The Types of Word Problems

In all three sets of word problems there were ten types of word problems which were presented in a different order in each set. The list below describes the types and gives an example of each.
Prices and quantities.
Example: A farmer sells his produce at the weekly market fair. He sells carrots for $3 a bag and tomatoes for $5.50 a bag. If he sells 57 bags all together and received $251, how many bags of each did he sell?

Money.
Example: Tom has 5 more dimes than quarters. How many of each coin does he have if the total value of the coins is $3.30?

Ratios.
Example: Divide 84 into 4 parts, so that the first is to the second as 2 to 3. The second to the third is 3 to 4 and the third to the fourth as 4 to 5. What are the numbers?

Mixtures.
Example: A photographer uses 2 types of developer solutions. One type is a 5% solution and the other is a 20% solution. For a particular job, she requires 30 litres of a 15% solution. How much of each should she mix?
Time, speed and distance.
Example: It takes James 12 hours to drive from Vancouver to Williams Lake and back. The distance going one way is 286 km. If James's rate going was 8 km per hour faster than his rate on the return trip, find his average speed in each direction.

Area and Perimeter.
Example: The sum of the length, width and height of a rectangular box is 75 centimetres. The length is twice the sum of the width and height. Twice the width exceeds the height by 5 cm. Find the dimensions of the box.

Age.
Example: The ages of a father and son total 51 years. In 9 years, the father will be twice as old as the son. How old is each now?

Consumer.
Example: If you decided to borrow $1000 from the bank so you may buy a car, how much money will you owe the bank after 3 years if you made no payments during that time and the
bank loans at 24% interest compounded annually?

**Three components.**

Example: The three most populous countries of the world are China, India, and The Soviet Union, with a combined population of 1,650 million people. Two hundred million more people live in China than in India, and the combined population of India and the Soviet Union is 50 million more than that of China. How many people live in each country?

**Others.** Any other problem which did not fall into any of the above categories.

**Polya’s Model of Problem Solving**

Before the beginning of the second week of the treatment, students received guidelines (see Appendix G) for problem solving based on Polya’s (1957) model of problem solving. A brief discussion followed and points in the guideline were clarified. Students were asked to refer to the guideline when they were experiencing difficulties solving a problem. In each subsequent period students were reminded that they should follow the four steps when they were
problem solving. Ideally, at the end of each session, a problem or two needed to be solved using the guideline. Because of time constraints this was not carried out and the effectiveness of the guideline was difficult to determine.

**Solving the Word Problems**

The Spreadsheet (Experimental) Group: Students in the Spreadsheet Group were taught the basic concept of how to solve word problems using the spreadsheet. Although an attempt was made at first to let them explore and find ways to solve the problems without instruction, only very few students managed to understand how to use the tool without formal instruction. Since time was limited and the discovery approach would have taken considerable time, the researcher had to demonstrate how to solve two problems. After instruction, the students demonstrated understanding of how to use the tool.

Problems on the spreadsheet were presented at the top of the screen and a space of one computer screen was left as work space. Students were expected to solve problems on the spreadsheet as is shown in the following screen examples:
Problem 1:
Roger has 6 times as many dimes as nickels and 3 times as many pennies as nickels. If he has $17.00, how many coins of each does he have?

<table>
<thead>
<tr>
<th>Pennies</th>
<th>Nickels</th>
<th>Dimes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>3xD9</td>
<td>1</td>
</tr>
<tr>
<td>Value</td>
<td>6xD9</td>
<td>6</td>
</tr>
</tbody>
</table>
Problem 1:
Roger has 6 times as many dimes as nickels and 3 times as many pennies as nickels. If he has $17.00, how many coins of each does he have?

Pennies Nickels Dimes

Number 3 1 6
Value .03 .05 .6

Type entry or use 2 commands

2-? for Help
1. Problem 1:
   Roger has 6 times as many dimes as nickels and 3 times as many pennies as nickels. If he has $17.00, how many coins of each does he have?

<table>
<thead>
<tr>
<th>Pennies</th>
<th>Nickels</th>
<th>Dimes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>3×D9</td>
<td>4</td>
</tr>
<tr>
<td>Value</td>
<td>.01×C9</td>
<td>.05×D9</td>
</tr>
</tbody>
</table>

   Expected value is $17.00

Value is +C11+D11+E11

---

Type entry or use 2 commands  2-? for Help
1. Roger has 6 times as many dimes as nickels and 3 times as many pennies as nickels. If he has $17.00, how many coins of each does he have?

<table>
<thead>
<tr>
<th>Pennies</th>
<th>Nickels</th>
<th>Dimes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>Value</td>
<td>.3</td>
<td>.5</td>
</tr>
</tbody>
</table>

Expected value is $17.00

Value is $6.80
Problem 1:
Roger has 6 times as many dimes as nickels and 3 times as many pennies as nickels. If he has $17.00, how many coins of each does he have?

<table>
<thead>
<tr>
<th>Pennies</th>
<th>Nickels</th>
<th>Dimes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>69</td>
<td>23</td>
</tr>
<tr>
<td>Value</td>
<td>.69</td>
<td>1.15</td>
</tr>
</tbody>
</table>

Expected value is $17.00
Value is 15.64

---

Type entry or use 2 commands

Problem 1:
Roger has 6 times as many dimes as nickels and 3 times as many pennies as nickels. If he has $17.00, how many coins of each does he have?

<table>
<thead>
<tr>
<th>Pennies</th>
<th>Nickels</th>
<th>Dimes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>75</td>
<td>25</td>
</tr>
<tr>
<td>Value</td>
<td>.75</td>
<td>1.25</td>
</tr>
</tbody>
</table>

Expected value is $17.00
Value is 17.00

---

Type entry or use 2 commands
Problem 1:
Roger has 6 times as many dimes as nickels and 3 times as many pennies as nickels. If he has $17.00, how many coins of each does he have?

<table>
<thead>
<tr>
<th>Pennies</th>
<th>Nickels</th>
<th>Dimes</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>14</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>16</td>
<td>17</td>
<td>9</td>
</tr>
<tr>
<td>18</td>
<td>19</td>
<td>12</td>
</tr>
</tbody>
</table>

Type entry or use 2 commands

2-? for Help
The Computer-As-Calculator (Control) Group: For students using the computer-as-calculator, the computer was used to present the problem and do calculations. Each problem was presented at the top of the screen and the rest of the screen was left for calculations.

This is how the screen looked:

From an automatic coffee maker a person can get a cup of coffee with cream and sugar for 25 cents. and a cup of coffee without cream and sugar for 20 cents. At the end of the day there was $8.45 in the machine and 36 cups have been used. How many cups of coffee with cream and sugar were sold.

$\text{? } 36 \times 25$
$900$
$\text{? } 36 \times 20$
$720$

TO SEE PROBLEM 9 TYPE 'RUN PROBLEM 9'

The computer was used instead of a stand alone calculator because studies have shown that students
who use a computer are more motivated to learn than students who do not use the computer (Malone, 1981; O’Shea & Self, 1982). To eliminate the possibility of the actual use of the computer being an extraneous variable which might affect the results, the researcher decided that both groups would use the computer. Although most students commented on the fact that the computer was nothing more than a calculator, there are some advantages to using the computer-as-calculator over a stand alone calculator. The main advantage is that it is possible to see the whole arithmetic operation which is taking place as well as being able to see the last four operations performed. In addition, having the problem on the screen all the time and performing the operations just below can be seen as advantageous to moving back and forth between the paper and calculator.

**Dependent Measures**

Three types or sets of data were collected for this study. The following is a description of each:

**The Posttest.** The purpose of the posttest was to determine the overall right or wrong solutions to
problems presented to the students. Although other studies (Blake, 1976; Kilpatrick, 1967; Wheatley, 1980) determine students' right or wrong solutions just from problems presented to them as they 'think-aloud', this study is different in that it collects the 'right-wrong solution' type of data from a separate posttest as well as from the 'think-aloud' problems. This additional posttest stems from the assumption that some students might be somewhat nervous during the 'think-aloud' interview, and as result be less able to solve problems correctly. The posttest, therefore, is supposed to eliminate those intrusions students might experience as they solve problems and think-aloud at the same time.

The posttest consisted of ten word problems which had to be solved in one period of 75 minutes. Of the ten, only one was an unfamiliar and extraordinary type of a problem. The rest of the problems were similar in type to those problems the students solved during the treatment period and in class. During the posttest, unlike during the treatment, students were not allowed to cooperate or share their ideas. Each student worked alone on his or her own computer and set of problems.
The correctness of the problem was determined according to the numeric of the final solution. No consideration was given to the process of arriving at the solution.

**The Think-Aloud Interview.** The purpose of the think-aloud interview was to collect data which would shed light on the problem solving strategies and processes each student used.

Each student was given a time in which she or he had to be interviewed. The ordering of the interviews was done randomly from both groups put together. Most interviews took place in the computer lab at times when no other classes were using the computer. Each interview took approximately 45 minutes to one hour. Students were given a standard explanation (see Appendix E) of what is required of them and the purpose of the interview.

In all, students had to solve six problems. The first problem was a trial to allow students to get used to solving problems and think aloud at the same time. Students in the spreadsheet group solved three problems with the aid of the spreadsheet and two
problems like the computer-as-calculator group, using paper and pencil and the spreadsheet only for calculations. The last two problems were solved without the spreadsheet so a comparison could be made to see if the use of the spreadsheet has affected their performance when they did not use the spreadsheet. Students from the computer-as-calculator group solved the remaining five problems as they had done before.

The problems (see Appendix D), except for the first problem, were ordered differently for each student. Of the six problems two were similar in type. Students in the spreadsheet group had to solve one of two problems similar in type using the spreadsheet and the other using pencil and paper.

The data for this section are mainly frequency counts based on the analysis of the interview protocols. To determine which and how many problem solving processes were used for each problem by each student, a coding form for the analysis of the protocols was developed (see Figure 6). The development of the coding form is a modification of a
<table>
<thead>
<tr>
<th>Action</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rereads</td>
<td></td>
</tr>
<tr>
<td>Own words</td>
<td></td>
</tr>
<tr>
<td>Clarifies data</td>
<td></td>
</tr>
<tr>
<td>Recalls related problem</td>
<td></td>
</tr>
<tr>
<td>Recall problem type</td>
<td></td>
</tr>
<tr>
<td>Draws table/diagram</td>
<td></td>
</tr>
<tr>
<td>Modify table/diagram</td>
<td></td>
</tr>
<tr>
<td>Identify variable</td>
<td></td>
</tr>
<tr>
<td>Identify relevant data/concept</td>
<td></td>
</tr>
<tr>
<td>Identify theorem</td>
<td></td>
</tr>
<tr>
<td>Divides problem into subproblems</td>
<td></td>
</tr>
<tr>
<td>Makes connection</td>
<td></td>
</tr>
<tr>
<td>Unable to make connection</td>
<td></td>
</tr>
<tr>
<td>Works toward goal/subgoal</td>
<td></td>
</tr>
<tr>
<td>Searches for a pattern</td>
<td></td>
</tr>
<tr>
<td>Reasons deductively</td>
<td></td>
</tr>
<tr>
<td>Insight/bright idea</td>
<td></td>
</tr>
<tr>
<td>Trial &amp; error/guess</td>
<td></td>
</tr>
<tr>
<td>Estimate/successive approx</td>
<td></td>
</tr>
<tr>
<td>Questions approach</td>
<td></td>
</tr>
<tr>
<td>Changes approach/another method</td>
<td></td>
</tr>
<tr>
<td>Checks the solution</td>
<td></td>
</tr>
</tbody>
</table>

Figure 6. Coding form for the analysis of protocols
number of other coding forms developed by Blake (1976), Kilpatrick (1967), Lucas et al. (1979) and Wheatley (1980). The coding form was designed in such a way that both the processes and the order in which they occurred were recorded.

The following is an example of how the interview protocols were decoded by the researcher:

Example 1 (from the spreadsheet group)

Mrs. Dehardy drove 90 kilometres on the way to visit her sister. She averaged 15 kilometres per hour more on the return trip than she did on her trip going. If the total travel time was 3 and 1/2 hours, what was her rate on the return trip?

So I'll just make two things right away for trip there and trip back. Leave some space between them... right here I'll just put in the speed, time, and distance. She drove 90 kilometres one way to visit her sister and averaged 15 kilometres more on the return trip than on the trip going so on the return trip
she averaged more. Ok, so I'll try speed on the trip back will be the trip there + 15. Ok. total travel time is...both things are 90 for distance. I'll just put those in. And then, the time, I'll just divide distance by the speed. yea, distance divided by the speed. Ok then I'll just plug in the total time so I can do it with c. I've got the total time. That would be...add the two times together then I should be able to function with the speed, distance and time here, now 60, ok. try, it goes down, yea, I'll have to try less, 50. off a point, so its getting closer. 45, so I guess I got 3-1/2 hours total time. (rereads the whole question). Yea ok. that's the answer.

Example 2 (from the computer-as-calculator group)

J - The employee's savings plan at the MMC Company wants an annual income of $500 from an investment of $9000. They plan to invest part of the money at 5% and the remaining amount at 6%. How much should they invest at each?
Ok. One column for 4% and ... no, one column for 5% and one column for 6%. = \text{prt.} \quad \text{(pause)} \quad \text{They want the interest to be 500 so the interest at 5\% is } i \quad \text{and the interest at 6\% is } 500 - i.

\text{Principal, no that's wrong.}

Ok. The amount that they want to invest the principal at 5\% is } p \text{ and then the principal at 6\% is } 9000 - p \text{ and the rate at 5\% is 5\% and the rate at 5\% is 6\% and the time is one year. } i = 5\% \text{ of } p \quad \text{for 5\% and at 6\% } i = 6\% \text{ of } 9000 - p \text{ so the interest for both of them, } 0.05p + 0.06 \times 9000 - p \text{ is } 500. \quad 0.06 \times 9000 \quad \text{(long pause)}

0 - so what you have is } 0.05p + 540 - 0.06p = 500. \quad 40 = 0.01p. \quad \text{Now you want to find principal.}

J - is 40 divided by \text{.01. } 4000. \quad \text{So } 4000 \text{ at 5\% and } 9000 - 4000 \text{ is } 5000 \text{ at 6\%.}

0 - ok.
An inter-coder reliability measurement was taken to establish the degree of reliability between two coders coding the same segments. The first coder was the researcher himself and the second coder was trained by the researcher to use the coding system which was specifically designed for this study. The researcher coded all the protocols first and only then trained the second coder. The second coder coded 34 segments out of 110 possible segments. Eighteen segments were taken from the computer-as-calculator group, and sixteen segments were taken from the spreadsheet group. Each segment consisted of a problem from the six think-aloud problems. Since some processes and strategies are similar to each other, they were put in clusters and coded the same (see Figure 7). Clustering similar processes and strategies was suggested by Lucas et. al. (1982) to avoid different interpretations of similar processes by two or more coders. In addition to clustering coding symbols, each coder was given the student's worksheet.
Cluster Code | Description
---|---
A | Rereads, own words, clarifies data.
B | Recalls related problem, recalls problem type.
C | Draws table/diagram, modifies table/diagram.
D | Identify relevant data/concept, makes connection, reasons deductively.

Figure 7. Cluster definitions.

The formula used for determining the degree of agreement between the two coders was taken from Lucas et al. (1982) and looked as follows:

\[ P = \frac{A(x,y)}{\text{Ave}(S(x), S(y))} \]
A \( (x,y) \) represents the number of agreements in the two codings and \( \text{Ave} (S(x), S(y)) \) represents the number of code symbols used by the two coders. The following example illustrates how the formula works:

Segment 10 \[ P = \frac{14}{(17+15)/2} = .88 \]

<table>
<thead>
<tr>
<th>Segment</th>
<th>Agreement</th>
<th>Total Coder 1</th>
<th>Total Coder 2</th>
<th>Total Agreement Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13</td>
<td>14</td>
<td>14</td>
<td>.93</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>.92</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>13</td>
<td>13</td>
<td>.85</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>1.00</td>
</tr>
<tr>
<td>5</td>
<td>9</td>
<td>11</td>
<td>11</td>
<td>.82</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>.80</td>
</tr>
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<td>7</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td>.80</td>
</tr>
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<td>8</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>.77</td>
</tr>
<tr>
<td>9</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>.83</td>
</tr>
<tr>
<td>10</td>
<td>14</td>
<td>17</td>
<td>15</td>
<td>.88</td>
</tr>
<tr>
<td>11</td>
<td>6</td>
<td>7</td>
<td>7</td>
<td>.86</td>
</tr>
<tr>
<td>12</td>
<td>6</td>
<td>7</td>
<td>9</td>
<td>.75</td>
</tr>
<tr>
<td>13</td>
<td>10</td>
<td>11</td>
<td>11</td>
<td>.91</td>
</tr>
<tr>
<td>14</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>.87</td>
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<td>15</td>
<td>11</td>
<td>14</td>
<td>18</td>
<td>.69</td>
</tr>
<tr>
<td>16</td>
<td>10</td>
<td>13</td>
<td>14</td>
<td>.74</td>
</tr>
<tr>
<td>17</td>
<td>5</td>
<td>7</td>
<td>7</td>
<td>.71</td>
</tr>
<tr>
<td>18</td>
<td>8</td>
<td>8</td>
<td>10</td>
<td>.89</td>
</tr>
</tbody>
</table>

Coder Pair Average

.83

Figure 8. Intercoder Agreement (Two Coders):

Computer-as-calculator Group
The overall agreement between the two coders in the thirty four segments is $P = .836$

**The Questionnaire**

A questionnaire (see Appendix H) was handed to the students at the end of each interview. The purpose of the questionnaire was to get a further insight into what the
students thought of the spreadsheet on the one hand and the computer-as-calculator on the other hand.
RESULTS

For this chapter three basic sets of data were collected and analyzed from the following sources:

1) The Posttest

2) The Think-aloud Interview

3) The Questionnaire

Results from the Posttest

For the posttest, students had to solve ten word problems of various types. The students were marked according to whether the solution to the problem was correct or incorrect (see Table 1). Using Analysis of Variance there was no statistically significant difference in score between the two groups. Although there were 15 students in each group during the treatment, only 14 students from each group showed up for the posttest.
Table 1
Number Of Correct Solutions Per Student.

<table>
<thead>
<tr>
<th>GROUP</th>
<th>NUMBER CORRECT PER STUDENT</th>
<th>TOTAL</th>
<th>MEAN</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPREADSHEET</td>
<td>6 7 4 5 8 6 4 6 9 8 5 10 3 10</td>
<td>91</td>
<td>6.50</td>
<td>2.24</td>
</tr>
<tr>
<td>COMPUTER</td>
<td>9 10 5 5 10 6 5 5 6 6 6 5 1</td>
<td>85</td>
<td>6.07</td>
<td>2.33</td>
</tr>
</tbody>
</table>

The results of the posttest were also analyzed by the number of students who correctly answered each item. The results are shown in Table 2.

Table 2
Number Of Correct Solutions Per Problem

<table>
<thead>
<tr>
<th>PROBLEM</th>
<th>one two three four five six seven eight nine ten</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPREADSHEET</td>
<td>14 14 12 12 8 6 8 8 6 3</td>
</tr>
<tr>
<td>COMPUTER</td>
<td>12 13 14 10 3 5 10 13 2 3</td>
</tr>
</tbody>
</table>

Results from the Think-aloud Interview

For the Think-aloud interview students had to solve six problems. Students in the spreadsheet group had to solve the first four problems using the spreadsheet and
the last two problems like the computer-as-calculator group. This means that they used pencil and paper and the computer only for calculations. Problems four and six were of the same type, one solved using the spreadsheet and the other solved with the computer-as-calculator. In addition, problem one, although meant to be at first a trial problem, was included as part of the data to be analysed. This change occurred because students' ability to articulate their thoughts in problem one was just as good and clear as it was in the other problems. Those students who were articulate, were consistently so throughout the performance in the think-aloud, whereas those who were generally unclear had difficulty expressing themselves in all problems.

For the think-aloud interview only 28 of 30 students were interviewed. The other 2 students were unable to come due to illness. Of the 28 interviews only 20 interviews were transcribed and coded. Of the eight remaining interviews, seven students had difficulties articulating their thoughts and in one interview the audio tape was damaged. Although the eight remaining students could not be coded for the analysis of processes used to solve the problems, their final correct-incorrect solutions to the problems were used as data. For the first part of the analysis of the think-aloud interview there are fifteen
students in the spreadsheet group and thirteen in the computer-as-calculator group (see Tables 3 & 4). Of the twenty interviews which were transcribed and coded, eleven were from the spreadsheet group and nine were from the computer-as-calculator group.

The data was analyzed in two ways:

1) The number of correct solutions (as in the posttest) and the number solved correctly for each type of problem (see Tables 3 & 4).

2) The number and range of processes used (see Tables 5 to 12). The analysis was done on the following:
   a) All processes used for all word problems
   b) Ten selected processes used in all word problems.
   c) Ten selected processes used in the first four word problems.
   d) Ten selected processes used in the last two word problems.
   e) Ten selected processes used in problems four and six.
   f) The first five processes of the first four word problems.
Correct Solutions

Using Analysis of Variance there was a statistically significant difference in score between the spreadsheet and computer groups \(F = 9.45, \text{ df} = 1,26, p < 0.05\). The means and standard deviations are shown in Table 3.

Table 3
Number Of Correct Solutions Per Student.

<table>
<thead>
<tr>
<th>GROUP</th>
<th>NUMBER CORRECT PER STUDENT</th>
<th>TOTAL</th>
<th>MEAN</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPREADSHEET</td>
<td>3 6 5 6 6 5 5 1 6 6 6 4</td>
<td>74</td>
<td>4.93</td>
<td>1.44</td>
</tr>
<tr>
<td>n = 15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMPUTER</td>
<td>4 4 4 2 0 5 4 0 5 4 3 1 4</td>
<td>40</td>
<td>3.08</td>
<td>1.95</td>
</tr>
<tr>
<td>n = 13</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results of the analysis on the number of students who correctly answered each item indicated a noticeable difference between the groups in the number of students who solved the distance = time*rate type problem (spreadsheet = 14; computer = 1) and the three components type problem (spreadsheet = 13; computer = 7) (See Table 4).
Table 4
Number Of Correct Solutions Per Student.

<table>
<thead>
<tr>
<th>PROBLEM</th>
<th>one</th>
<th>two</th>
<th>three</th>
<th>four</th>
<th>five</th>
<th>six</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPREADSHEET</td>
<td>13</td>
<td>13</td>
<td>14</td>
<td>12</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>COMPUTER</td>
<td>7</td>
<td>9</td>
<td>1</td>
<td>7</td>
<td>7</td>
<td>9</td>
</tr>
</tbody>
</table>

Processes

Most of the analysis is targeted towards ten particular processes which were most frequently used and thought by the researcher to be most important to the problem solving process (see Tables 5 to 12). These ten processes correspond to the first two steps in Polya's model of problem solving, understanding the problem and devising a plan. Although most of the processes that were analyzed belong to these first steps, those which were omitted from the analysis are processes which do not contribute directly to solving the problem.
Comparison of all processes on the six problems.

Tables 5 and 6 describe the overall number of processes used by each group. Table 5 shows the frequency of each process and table 6 shows the number of processes used by each student.

Table 5

A Comparison of All Processes on the Six Problems.

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>COMPUTER (freq)</th>
<th>SPREADSHEET (freq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rereads</td>
<td>17</td>
<td>26</td>
</tr>
<tr>
<td>Own</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td>Clarifies</td>
<td>15</td>
<td>26</td>
</tr>
<tr>
<td>Rec.R.Pro</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Rec.P.Type</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Draw</td>
<td>19</td>
<td>48</td>
</tr>
<tr>
<td>Modify</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Variable</td>
<td>46</td>
<td>47</td>
</tr>
<tr>
<td>Concept</td>
<td>11</td>
<td>28</td>
</tr>
<tr>
<td>Theorem</td>
<td>12</td>
<td>25</td>
</tr>
<tr>
<td>Subproblem</td>
<td>67</td>
<td>109</td>
</tr>
<tr>
<td>Connection</td>
<td>88</td>
<td>126</td>
</tr>
<tr>
<td>Unable</td>
<td>13</td>
<td>21</td>
</tr>
<tr>
<td>Goal</td>
<td>49</td>
<td>66</td>
</tr>
<tr>
<td>Pattern</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Reasons</td>
<td>38</td>
<td>54</td>
</tr>
<tr>
<td>Insight</td>
<td>6</td>
<td>27</td>
</tr>
<tr>
<td>T + E</td>
<td>5</td>
<td>49</td>
</tr>
<tr>
<td>Estimate</td>
<td>2</td>
<td>44</td>
</tr>
<tr>
<td>Question</td>
<td>18</td>
<td>21</td>
</tr>
<tr>
<td>Change</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Check</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>TOTAL</td>
<td>443</td>
<td>778</td>
</tr>
<tr>
<td>MEAN</td>
<td>49.22</td>
<td>71.09</td>
</tr>
<tr>
<td>n = 9</td>
<td></td>
<td>n = 11</td>
</tr>
</tbody>
</table>
### Table 6

**Number of Processes Per Student**

<table>
<thead>
<tr>
<th></th>
<th>Number of All Processes Per Student</th>
<th>Total</th>
<th>Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SPREADSHEET</strong></td>
<td>70 84 82 83 74 61 62 64 99 46 46</td>
<td>1778</td>
<td>171.09</td>
<td>10.70</td>
</tr>
<tr>
<td><em>n = 11</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>COMPUTER</strong></td>
<td>47 47 48 63 49 57 39 49 44</td>
<td>1443</td>
<td>49.22</td>
<td>10.35</td>
</tr>
<tr>
<td><em>n = 9</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**A Comparison of Ten Selected Processes on the Six Problems.**

Tables 7 and 8 describe the ten selected number of processes used by each group. Table 7 shows the frequency of each process and table 8 shows the number of processes used by each student.

### Table 7

**A Comparison of Ten Selected Processes on the Six Problems.**

<table>
<thead>
<tr>
<th>PROCESSES</th>
<th>COMPUTER (freq)</th>
<th>SPREADSHEET (freq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draw</td>
<td>19</td>
<td>48</td>
</tr>
<tr>
<td>Variable</td>
<td>46</td>
<td>47</td>
</tr>
<tr>
<td>Concept</td>
<td>11</td>
<td>28</td>
</tr>
<tr>
<td>Theorem</td>
<td>12</td>
<td>25</td>
</tr>
<tr>
<td>Subproblem</td>
<td>67</td>
<td>109</td>
</tr>
<tr>
<td>Connection</td>
<td>88</td>
<td>126</td>
</tr>
<tr>
<td>Goal</td>
<td>49</td>
<td>66</td>
</tr>
<tr>
<td>Reasons</td>
<td>38</td>
<td>54</td>
</tr>
<tr>
<td>Insight</td>
<td>6</td>
<td>27</td>
</tr>
<tr>
<td>T + E</td>
<td>5</td>
<td>49</td>
</tr>
<tr>
<td>Estimate</td>
<td>2</td>
<td>44</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>343</strong></td>
<td><strong>623</strong></td>
</tr>
<tr>
<td><strong>MEAN</strong></td>
<td>38.11</td>
<td>56.63</td>
</tr>
<tr>
<td><em>n = 9</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>n = 11</em></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 8

**Number Of Selected Processes Per Student**

<table>
<thead>
<tr>
<th>STUDENT</th>
<th>NUMBER OF SELECTED PROCESSES PER TOTAL</th>
<th>MEAN</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPREADSHEET</td>
<td>54 53 62 63 58 52 54 79 45 50 53 1623</td>
<td>156.63</td>
<td>19.01</td>
</tr>
<tr>
<td>COMPUTER</td>
<td>37 41 37 42 38 41 30 38 39</td>
<td>1343</td>
<td>138.11</td>
</tr>
</tbody>
</table>

**Comparison of selected processes on the first four problems.** The first four problems which were solved by the spreadsheet group were solved solely using the spreadsheet. A comparison between the first four problems in each group gives a clear indication of the differences between the groups.
Table 9

A Comparison of Selected Processes on the First 4 Problems

<table>
<thead>
<tr>
<th>PROCESSES</th>
<th>COMPUTER (freq)</th>
<th>SPREADSHEET (freq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draw</td>
<td>11</td>
<td>41</td>
</tr>
<tr>
<td>Variable</td>
<td>32</td>
<td>29</td>
</tr>
<tr>
<td>Concept</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>Theorem</td>
<td>8</td>
<td>21</td>
</tr>
<tr>
<td>Subproblem</td>
<td>44</td>
<td>80</td>
</tr>
<tr>
<td>Connection</td>
<td>65</td>
<td>91</td>
</tr>
<tr>
<td>Goal</td>
<td>35</td>
<td>44</td>
</tr>
<tr>
<td>Reasons</td>
<td>27</td>
<td>40</td>
</tr>
<tr>
<td>Insight</td>
<td>3</td>
<td>22</td>
</tr>
<tr>
<td>T + E</td>
<td>4</td>
<td>49</td>
</tr>
<tr>
<td>Estimate</td>
<td>1</td>
<td>44</td>
</tr>
<tr>
<td>TOTAL</td>
<td>234</td>
<td>485</td>
</tr>
<tr>
<td>MEAN</td>
<td>26.00</td>
<td>44.09</td>
</tr>
</tbody>
</table>

Some of the most outstanding differences between the groups concern drawing a table/diagram (sp = 41 co = 11), decomposing the problem into subproblem (sp = 80 co = 44), insight (sp = 22 co = 3), trial and error (sp = 49 co = 4) and estimating (sp = 44 co = 1).

Comparison of selected processes on the last two problems. The comparison between the last two problems is a comparison between two similar methods of solving the problems. Students from both groups used pencil and paper and the computer only as a calculator. There appears to be
no differences in the number of processes used between the two groups on these two problems.

Table 10

A Comparison of Selected Processes on the Last Two Problems

<table>
<thead>
<tr>
<th>PROCESSES</th>
<th>COMPUTER (freq)</th>
<th>SPREADSHEET (freq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draw</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Variable</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>Concept</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Theorem</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Subproblem</td>
<td>23</td>
<td>29</td>
</tr>
<tr>
<td>Connection</td>
<td>23</td>
<td>35</td>
</tr>
<tr>
<td>Goal</td>
<td>14</td>
<td>22</td>
</tr>
<tr>
<td>Reasons</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>Insight</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>T + E</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Estimate</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>109</td>
<td>142</td>
</tr>
<tr>
<td>MEAN</td>
<td><strong>12.11</strong></td>
<td><strong>12.90</strong></td>
</tr>
</tbody>
</table>

Comparison of selected processes on problems four and six. Problems four and six are of the same type. The spreadsheet group solved problem four with the aid of the spreadsheet and problem six using pencil and paper.
A comparison between the two problems indicates that in problem four students from the spreadsheet group used the ten targeted processes more times compared to themselves in problem six and compared to the computer group in problem four. In the computer group there is no difference between the number of targeted processes used in problems four and six.

First five responses on the first four problems.

The purpose of this comparison is to determine which
first five processes were used in each group. This comparison can shed light on the type of strategies students use when they approach a problem. Considerable differences were found between drawing a table/diagram (sp = 39 co = 10), identifying the variable (sp = 16 co = 29), decomposing the problem into subproblems (sp = 55 co = 36) and working towards a goal (sp = 5 co = 18).

Table 12
A Comparison Between the First 5 Responses of the First 4 Problems

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>COMPUTER (freq)</th>
<th>SPREADSHEET (freq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rereads</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>Own</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Clarifies</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Rec.R.Pro</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Rec.P.Type</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Draw</td>
<td>10</td>
<td>39</td>
</tr>
<tr>
<td>Modify</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Variable</td>
<td>29</td>
<td>16</td>
</tr>
<tr>
<td>Concept</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Theorem</td>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td>Subproblem</td>
<td>36</td>
<td>55</td>
</tr>
<tr>
<td>Connection</td>
<td>43</td>
<td>37</td>
</tr>
<tr>
<td>Unable</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Goal</td>
<td>18</td>
<td>5</td>
</tr>
<tr>
<td>Pattern</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Reasons</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Insight</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>T + E</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Estimate</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Question</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Change</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Check</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>
Results from the Questionnaire

The results for each item in the given questionnaire are as follows:

1) Having used the spreadsheet/computer, would you use it again?

<table>
<thead>
<tr>
<th>Reply</th>
<th>SPREADSHEET</th>
<th></th>
<th>COMPUTER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Percent</td>
<td>No.</td>
</tr>
<tr>
<td>Yes</td>
<td>15</td>
<td>100%</td>
<td>9</td>
</tr>
<tr>
<td>No</td>
<td>0</td>
<td>0%</td>
<td>4</td>
</tr>
</tbody>
</table>

2) If you had unlimited access to the computer, would you use the spreadsheet/computer to help you solve Maths problems?

<table>
<thead>
<tr>
<th>Reply</th>
<th>SPREADSHEET</th>
<th></th>
<th>COMPUTER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Percent</td>
<td>No.</td>
</tr>
<tr>
<td>Yes</td>
<td>11</td>
<td>74%</td>
<td>6</td>
</tr>
<tr>
<td>No</td>
<td>0</td>
<td>0%</td>
<td>1</td>
</tr>
<tr>
<td>Consider</td>
<td>4</td>
<td>26%</td>
<td>6</td>
</tr>
</tbody>
</table>
3) If you had to 'hassle' to get computer time, would you make the effort to use the spreadsheet/computer to help you solve maths problems?

<table>
<thead>
<tr>
<th>Reply</th>
<th>SPREADSHEET</th>
<th></th>
<th></th>
<th>COMPUTER</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Percent</td>
<td></td>
<td>No.</td>
<td>Percent</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>0</td>
<td>0%</td>
<td></td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>6</td>
<td>40%</td>
<td></td>
<td>7</td>
<td>54%</td>
<td></td>
</tr>
<tr>
<td>Consider</td>
<td>9</td>
<td>60%</td>
<td></td>
<td>6</td>
<td>46%</td>
<td></td>
</tr>
</tbody>
</table>

4) Did you enjoy using the spreadsheet/computer to solve word problems?

<table>
<thead>
<tr>
<th>Reply</th>
<th>SPREADSHEET</th>
<th></th>
<th></th>
<th>COMPUTER</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Percent</td>
<td></td>
<td>No.</td>
<td>Percent</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>13</td>
<td>87%</td>
<td></td>
<td>6</td>
<td>46%</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>0</td>
<td>0%</td>
<td></td>
<td>0</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Sometimes</td>
<td>2</td>
<td>13%</td>
<td></td>
<td>7</td>
<td>54%</td>
<td></td>
</tr>
</tbody>
</table>
5) Has using the spreadsheet/computer made you aware of different strategies for solving word problems? Please elaborate.

<table>
<thead>
<tr>
<th>Reply</th>
<th>SPREADSHEET</th>
<th>COMPUTER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Percent</td>
</tr>
<tr>
<td>Yes</td>
<td>11</td>
<td>73%</td>
</tr>
<tr>
<td>No</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>A bit</td>
<td>4</td>
<td>27%</td>
</tr>
</tbody>
</table>

6) Do you think you would be able to use the strategies without the spreadsheet/computer?

<table>
<thead>
<tr>
<th>Reply</th>
<th>SPREADSHEET</th>
<th>COMPUTER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Percent</td>
</tr>
<tr>
<td>Yes</td>
<td>3</td>
<td>20%</td>
</tr>
<tr>
<td>No</td>
<td>1</td>
<td>7%</td>
</tr>
<tr>
<td>A bit</td>
<td>11</td>
<td>73%</td>
</tr>
</tbody>
</table>
The following are typical responses for the open ended questions from both groups:

Question 5: Has using the spreadsheet/computer made you aware of different strategies for solving word problems?

Spreadsheet Group:

Barb: It has taught me how to set up word problems and how to sort out the known facts. I think I could solve problems with the spreadsheet that I couldn't solve on paper and especially a lot faster. I think it's great and I would strongly prefer it to paper. It is also easier to edit and add in things.

Tim: You can see different ways for solving problems. It can help you find the easiest way to solve a problem, rather than having to work it out the most difficult way.

Tracy: The spreadsheet works like a chart and I don't usually use charts. It's helped me to organize my work and my thoughts when solving word problems.
Computer Group

Pat: I could have done all the calculations using a calculator.

Question 6: Do you think you would be able to use the strategies without the computer? Please elaborate.

Spreadsheet Group:

Paul: It would take longer in some cases and other methods might work better, but by using the calculator and making reasonable guesses it would still certainly help to solve a problem. I have used a spreadsheet style setup in some of my in-class math problems since learning how it works.

Craig: I would be able to use the chart without the computer, but the best part about the spreadsheet is being able to use trial and error. This takes much too long without the computer.

Khai: If you thought about it as if you were doing it on the spreadsheet, some of the strategies may come to mind. Actually, I have thought about what I would
have done on the computer when I was involved in tough situations.

Computer Group

Beth: Yes the computer is just an expensive calculator. I would do just as well with a small calculator.

Pat: I used the same strategies on the computer as I did with my calculator.

Question 7: Please make any additional comment you would like to make.

Spreadsheet Group

Jon: It was great using the spreadsheet. It made the work a lot more fun and interesting. It's also easier to understand some of the more difficult questions.

Paul: I am not a very good problem solver and the spreadsheet has helped me quite a bit. I don't think I would have solved some of the problems without it.

Dan: This has helped me set up equations in a much better way and understanding than before. I would
have to say that I have learned many new strategies with the spreadsheet. Now that I have learned most of those strategies, I am quite sure I can do most of them on paper. But the spreadsheet cuts down a lot of the time, working out, and room for error that I find on paper. All in all I really liked using the spreadsheet and I feel it would be a good thing for students to be able to use it on a regular basis.

Computer Group

Jay: Using the computer was more fun than calculator because it is the first time I have used it like this. I found that it took longer to type the equations than pushing buttons on the calculator.

Kam: Mainly, all the computer has been doing for me is calculating basic problems. It is useful to have the questions printed on a screen and work with, but other than that, it has just been a calculator.
The purpose of this study was to investigate the effect of using an electronic spreadsheet on the performance and problem solving processes of Grade 10 students as they solved algebraic word problems. To recapitulate, the four research questions were:

1) Do students using the spreadsheet solve more problems correctly than students using the computer-as-a-calculator?

2) Do students using the spreadsheet employ more problem solving processes and strategies than students using the computer-as-calculator.

3) Do students using the spreadsheet employ more of any specific kind of problem solving processes and strategies than students using the computer-as-calculator.

4) Do students using the spreadsheet employ different problem solving processes and strategies in their approach to problems than students using the computer-as-calculator?
Problem Solving Performance

Data from two sources were collected to determine whether students using the spreadsheet solved more problems correctly than the students who used the computer-as-a-calculator. The results from the posttest indicate that there is no difference between the two groups in the number of problems solved correctly. However, the results from the think-aloud interview indicate that there is a strong significant difference between the two groups in the number of problems solved correctly.

It is difficult to conclude from the inconsistent results whether the use of the spreadsheet has any effect on the performance of students. Perhaps an additional posttest could have shed more light on the performance of the two groups. However, it is important to elaborate on the different circumstances under which students had to solve the word problems. In the posttest, students had to solve the word problems without any interruption. In the think-aloud interview, students had to verbalize their thoughts as they solved the problems. It is possible that this format variable (having to think aloud) was a contributing factor to the difference in results. By
having to think aloud and use the spreadsheet at the same time, students may have become aware of strategies and processes they used, as well as become more organized in their thought, which in turn contributed to the higher level performance.

Problem Solving Processes

A comparison between the two groups on the number of processes used in all process categories indicates that students using the spreadsheet used more strategies and processes than students in the computer-as-calculator group ($\bar{X}_{sprd} = 71.1$; $\bar{X}_{comp} = 49.2$). A comparison between the two groups on the number of processes used in ten selected processes of the first four word problems indicates that students in the spreadsheet group used more processes and strategies than students in the computer-as-calculator group ($\bar{X}_{sprd} = 44.1$; $\bar{X}_{comp} = 26.0$). A comparison between the two groups on the number of processes used in ten selected processes of the last two problems indicates that there was no difference in the number of processes used ($\bar{X}_{sprd} = 12.9$; $\bar{X}_{comp} = 12.1$). An additional comparison between problems four and six indicates that students in the spreadsheet group used more processes in
problem four than they did in problem six. They also used more processes in problem four in comparison with problems four and six of the computer-as-calculator group. ($\bar{x}_{\text{comp4}} = 5.1$, $\bar{x}_{\text{comp6}} = 4.8$; $\bar{x}_{\text{sprd4}} = 10.2$, $\bar{x}_{\text{sprd4}} = 4.6$).

The evidence above indicates that when using the spreadsheet to solve word problems students use more processes and strategies. However, when deprived of the spreadsheet, students in the spreadsheet group did not use more strategies and processes in comparison to the control group. It is important to mention that except for the type of tool used to solve the problems, all variables in the study, such as subject, task and situation, were the same in both groups. This leads to the conclusion that only the tool used, namely the spreadsheet, was the contributing factor in the number of processes and strategies used. One may conclude that the use of the spreadsheet prompts students to use more problem solving processes.

Specific Problem Solving Processes

Students using the spreadsheet used some specific processes and strategies significantly more in comparison with the computer-as-calculator group. For example, in a comparison of ten selected processes
used in the first four problems
(computer-as-calculator: \( n = 9 \); spreadsheet: \( n = 11 \)),
the most outstanding differences were: drawing a table
or diagram (\( sp = 41; co = 11 \)), decomposing the problem
into subproblems (\( sp = 80; co = 44 \)), insight (\( sp = 22; co = 3 \)),
trial and error (\( sp = 49; co = 4 \)), estimating
(\( sp = 44; co = 1 \)). Although the use of other processes
differed as well, the five mentioned above showed
distinctly more differences.

As discussed in Chapter 2, decomposing the
problem into subproblems and drawing a diagram or
table are considered crucial to the problem solving
process (Flake, McClintock & Turner, 1985; Osborne &
Kasten, 1980). The spreadsheet environment prompts
students to use these processes constantly, as the
data from this study suggest. Students learn to
organize their thoughts by creating tables and
dividing the problem into subproblems. The tool which
in this case was the spreadsheet, is a medium through
which these essential processes can be practiced and
constantly used. Although the use of trial and error
and estimation processes has been ignored in the past,
research suggest these processes also need to be
included as part of the problem solving process
(Musser & Shaughnessy, 1980; Reys et al., 1982; Schoen
et al., 1983). The use of the spreadsheet allows students to use these processes frequently. The means by which a problem is solved on the spreadsheet makes it necessary to use trial and error and estimation as well as to decompose the problem into subproblems and create tables.

The spreadsheet also enables students to have insight as they solve problems. It is not clear if the insight occur because students are able to see instantly on the computer screen how all the components of the problem affect each other when the numerical value of the variable is changed. A different possibility is that since the problem is divided so clearly into subproblems each containing a formula which corresponds to that part of the problem, it is easy to debug the problem.

Approach to Solving Problem

Students using the computer-as-calculator used more of the following problem solving processes in the first five responses of the first four problems compared with students in the spreadsheet group: Identify the variable \( (co = 29; sp = 16) \), work towards a goal or subgoal \( (co = 18; sp = 5) \). Students using the spreadsheet used more of the following problem
solving processes: Draw a table or diagram (sp = 39; co = 10), decompose problem into subproblems (sp = 55; co = 36).

The data above does suggest that students using the spreadsheet use different problem solving processes in their approach to problems. Students in the computer-as-calculator group give priority to identifying a variable and putting it into an equation. Students in the spreadsheet group give priority to dividing the problem into subproblems and putting the subproblems into a table from which they can continue to solve the problem. However, one cannot say that decomposing the problem into subproblems at the start of the problem solving process is more important than identifying the variable. It does suggest that the spreadsheet can be a useful tool for students whose style of problem solving is to approach the problem through decomposing the problem into subproblems and putting the subproblems into a table.

Students' Verbal Responses

Students in the spreadsheet group generally thought that the spreadsheet was a helpful tool in solving word problems. The following are some of their responses: Having used the spreadsheet/computer, would
you use it again to solve word problems?
Yes (sp = 100%; co = 69%).

Did you enjoy using the spreadsheet/computer to solve word problems? Yes (sp = 87%; co = 46%).

Has using the spreadsheet/computer made you aware of different strategies for solving word problems?
Yes (sp = 73%; co = 15%).

Written comments from students in the spreadsheet group were very positive (see Chapter 4 and Appendix I). Written comments from students in the computer-as-calculator group showed indifference to the use of the computer-as-a-calculator.

The purpose of the questionnaire was to determine students' subjective thoughts and feelings about the tools they used to solve word problems. Undoubtedly students in the spreadsheet group showed greater interest and enthusiasm. They felt the tool enabled them to solve problems in a manner they never used before. It opened the door to an alternative and truly effective approach to solving word problems. For some students, the spreadsheet changed the way they approach word problems, both in terms of strategies and processes. For other students, as they have commented both on paper and in private, word problems
need not be frightening and frustrating any more. They can be fun and enjoyable.

Some Informal Observations

What follows are some informal observations made by the researcher during the treatment period.

Motivation and Concentration. Compared to the students in the computer-as-calculator group, students in the spreadsheet group seemed to be more motivated and interested in solving the word problems. They were eager to come into the computer room and always commented on how much more fun it is to solve problems using the spreadsheet. While working on the problems they seemed to be more involved and concentrated. They talked less between themselves, yet when they did talk to each other it was mostly about the problems they needed to solve.

Task Persistence. Students in the spreadsheet group seemed more determined to start a problem and finish it. When unable to continue they would try and retry to enter different formulas or rearrange the problem on the spreadsheet. As a result of this "task persistence" students took more time to solve problems and at the end of a session they solved fewer problems
than students in the computer-as-calculator group. However, their solutions were mostly correct.

**Questions.** Students in the spreadsheet group usually asked less for help from the researcher. Yet when they did ask a question it was after they tried and thought of various possibilities. When students asked for help, the researcher would always ask them first what they had done and thought before asking for help.

**Implementing the Spreadsheet in Mathematics**

The data from this study strongly supports the use of the spreadsheet as a tool in solving problems. Students performed better and were more motivated to solve word problems once they started to use the spreadsheet. Yet with all the proof of the effectiveness of the tool and the enthusiasm from both teachers and students, it will take a long time to implement the spreadsheet as a tool to be used in the mathematics classroom. In the meantime, students who can greatly benefit from this tool will not be able to use it. The present structure of secondary mathematics curriculum leaves little, if any, time to incorporate this and other helpful tools. There is an urgent need to find ways of incorporating the spreadsheet into
mathematics curriculum. This is a practical concern which, if not addressed, will result in lost opportunities for students who may find the spreadsheet a useful tool in problem solving.

Suggestions for Future Research

As was mentioned in Chapter 3, the use of the spreadsheet as a tool in solving word problems has never been investigated before. This study is the first of its kind, and since it has proven to be an effective tool in solving problems, further research is recommended.

There are many possible studies that can be done to investigate the effects and possible uses of the spreadsheet in mathematical problem solving. For one, a study can be done to determine the performance of students using the spreadsheet. Results from the present study are ambiguous and need replication. An additional study can be done to investigate the effect of using the spreadsheet on the ability to produce symbolic representations (equations). Students in the spreadsheet group reported that they found creating equations easier after using the spreadsheet. It is possible that transfer occurs from the concrete (the spreadsheet) to the symbolic (the equation). Students
who find the transition from the concrete to the abstract too frustrating can use the spreadsheet to make the transition a less frustrating experience.

Problem Solving in the 1980s

The challenge and focus of mathematics education for the 1980s was proclaimed in 1980 to be problem solving (Krulik, 1980; Osborne & Kasten, 1980). The use of the spreadsheet to solve word problems is a step in this direction. The results of this study indicate that students who use the spreadsheet use more of, and more specific kinds of, problem solving processes and strategies. By using more problem solving processes and strategies, students become more closely acquainted with the problem solving process. The use of the spreadsheet also enables them to learn and practice some important processes which they seldom use otherwise. The ability to have a visual representation of the problem and see how the various elements of the problem are connected and affect each other makes it possible for students to solve problems in an untraditional way. It enables them to organize their thoughts and be less engaged by tedious calculations. The spreadsheet makes the variable(s) a concrete entity which is placed in a specific location...
on the spreadsheet. It is dynamic as opposed to being static.

All the qualities of the spreadsheet mentioned above are contributing factors to the effect the spreadsheet has on the problem solving performance of students. The spreadsheet is an example of how technology can be used to further the ability of our students to become better problem solvers, a goal that was set by the National Council of Teachers of Mathematics.
REFERENCES


Appendix A - Two Worksheets for the AppleWorks Spreadsheet
WORKSHEET 1

1)

a) Using the right arrow key —> how many columns are there all together on the spreadsheet?


b) Using the down arrow key, how many rows are there all together on the spreadsheet?


c) How many cells are there all together?


d) Move the cursor to cell AJ270. What's written in it?


e) Press (OA) and 1 at the same time. What happens?


2)

a) Go to cell B3. Press the SHIFT key and type HELLO. Then let go of the SHIFT key and type goodbye. What does the SHIFT key do?


b) Now you want to get rid of HELLO and goodbye, so press the (OA) and B at the same time. Look at the bottom of the screen and move the cursor
using the --> key to BLOCK. Press RETURN. To highlight the words you want to Blank use any combination of the arrow keys --> <-- . Press RETURN. What happened?________________________.
Type some more sentences and numbers and Blank them out.

c) Type Vancouver and make a spelling mistake. To correct the mistake press (OA) and U. Look at the bottom of the screen and using the arrow keys and the DELETE key correct the mistake. Try to do the same twice more.

You just learnt your first 2 very important COMMANDS and there are plenty to come. If you want to see all the COMMANDS there are press (OA) and ?. What happened?__________________________.

REMEMBER (OA) B for blank and (OA) U to correct mistakes.
3) Type the following into the spreadsheet:

**JOHN’S EXAMS RECORD:**

<table>
<thead>
<tr>
<th></th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Math</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>English</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>History</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social Studies</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>French</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Enter scores of up to 100 for John’s exams. Are you noticing something funny about the way the numbers are lined up? To correct this you need to use the \(<\text{OA}\)\ V command. Move the cursor to LABEL FORMAT and press RETURN. Move the cursor to RIGHT JUSTIFY and press RETURN. Any change?

Complete filling in the numbers in all the slots.

Now you want to find the AVERAGE of all John’s exams in September. Place the cursor to the right of TOTAL and the same column as September. Now, look at the September column and Math row to find the cell number of the Math score. Do the same for English, History etc.. Type (as an example) \((c9+c10+c11+c12)/5\). Why
use the brackets and why divide by 5?

Find the averages for the rest of the months.
Appendix A

On your last work sheet you learnt to use 3 very important commands: (OA) B which blanks an entry, (OA) U which edits an entry and (OA) V which sets standards for the value or label format. To make sure you know how to use these commands move your cursor to cell AA1 and blank out the 2 written lines.

Move to cell BA and correct the sentence from "You are learning to edit different cells" to "You are learning to edit different cells"

Sometimes you enter a word, a sentence or a number into a cell or a group of cells but before you press the RETURN key or one of the arrow keys you change your mind and want to start all over again. You can do that by pressing the ESC key (top left hand corner of the keyboard). Go to cell BA1 and write "Mary had a little lamb" but do not press the RETURN or any of the arrow keys. Instead press the ESC key.

What happened?

Remember the ESC key, it comes handy sometimes.

LABEL and VALUES: What is a label? A label is anything that has no numerical value. For example: a
word or a sentence are labels. Numbers can also be
'labels' but without numeric value.
What is a value? A value is anything that has numeric
value and can be manipulated as a number. For example:
If you put a value in one cell and a value in another
cell, you can add them up. But if you put in a number
as a 'label' in one cell and the same in the next cell
you cannot add them up because they have no numeric
value, they are labels.
How does the computer know when you want a label and
when you want a value? To get a label you either type
in a word and the computer will automatically know
it's a label or if you want a number as your first
entry type first " and then what ever you want.
To get a value either type a number first and the
computer will automatically know it's a value or if
you want the value of a certain cell (e.g D24+E23)
type + before the letter.
Let's do some exercises:

1) Go to cell AA1 and enter your name. Look at
the bottom left hand side of the screen. Does
it say label or value?__________.
2) Type the equation $5x + 23y = 250$. What happens when you type the equation without putting the " in front the equation? 

______________________________________________

What happens when you do put the " in front of the equation?______________________________________________

3) Type a number. Look at the bottom left hand side of the screen. Does it say label or value?________.

4) Go to cell AL1. Type a number in AL1, AL2, AL3, AL4. Put the cursor on AL5 and type +AL1+AL2 etc..... What happens if you want to do the same without putting the + in front of the

AL1?______________________________________________

5) Put the cursor on AL5 and blank whatever is there. Instead of adding +AL1+AL2 etc... you can add by doing the following...@sum(AL1...AL4). This will add all the numbers from cell AL1 to AL4. Make sure there are only 3 dots between the AL1 and the
Appendix A

AL4. The & sign is above the 2 (press SHIFT and 2).

Move the cursor to cell A64. In front of you is a chart depicting the partial finances of a record store. The spreadsheet helps the manager of the store keep track of the accounting. The first row of the chart is filled as an example.

Wholesale price refers to the price the store buys from the manufacturer. %Markup refers to the % of the wholesale price which will be added to make the retail price (the price for customers of the store).

1) Change the figure in the wholesale price, %markup and No. sold. What happens when you change each one of them? How does it effect the other numbers?

2) Fill in the rest of the chart in a similar manner to the LP row.

3) Explore with the numbers.

Create a chart for the following:

What will you owe a bank at the end of the year if you took a loan of $200 at 22%, $1000 at 18%, $3000 at 19.5% and $10000 at 12%. On the same chart find what
is the interest rate on a loan of $3500 which creates $500 in interest at the end of the year, $5000 which creates $230, and $300 which creates $19.
Appendix B - Three Sets of Word Problems Used in the Treatment.
Word Problems For Set # 1

John has grades of 92, 87, 75, 78 and 81 on five tests. What is the lowest grade John can have on the sixth test in order to maintain an average of 85?

A farmer sells his produce at the weekly market fair. He sells carrots for $3 a bag and tomatoes for $5.50 a bag. If he sells 57 bags all together and received $251, how many bags of each did he sell?

Tom has 5 more dimes than quarters. How many of each coin does he have if the total value of the coins is $3.30?

The sum of 3 numbers is 46. The first number is smaller than the second by 4 and the third number is twice as large as the second. What are the numbers?

On Monday, Mike and Steve shot baskets, and Mike made three times as many as Steve. On Tuesday, Mike made 7 fewer baskets than he did on Monday, while Steve made 9 more. If they tied on Tuesday, what were their scores on Monday?

Fourteen litres of coffee cream with a 10% butterfat content are needed for a banquet, but 4% milk and 18% cream are the only products available. How much of each should be bought to make the required mixture?

A cougar spots a deer 1/2 km away and immediately starts chasing the deer at 30 m/s. The deer notices the cougar after the cougar has already ran for 6 seconds. The deer starts running away at 27.5 m/s. How long does it take the cougar to catch up with the deer. At this point, how many metres has each ran?

The weight of two defensive linemen together is 280 kg. Three times the lighter exceeds twice the heavier by 115 kg. What is the mass of each player?
Anne and Barb are able to sell 120 subscriptions to a magazine in one week. If Anne could have sold 15 more, she would have sold twice as many as Barb. How many did each sell?

A rectangular room is 10 m longer than it is wide. If the perimeter of the room is 64 m, find the dimensions.

The ages of a father and son total 51 years. In 9 years, the father will be twice as old as the son. How old is each now?

A 1979 Toyota Celica costs $7000 to buy and 2.1 c/km to maintain. On the other hand a domestic Ford Escort costs $4850 to buy and 4.6 c/km to maintain. After how many kilometres will the two cars be equal in their total cost and maintenance?

The relationship between Fahrenheit and Celsius temperatures is given by the formula \( F = \frac{9}{5}C + 32 \).

a) Determine the Fahrenheit temperature corresponding to 100 Celsius.
b) Determine the Celsius temperature corresponding to 32 Fahrenheit.

Two trains left Vancouver and Kamloops which are 500 km apart. They were moving toward each other on parallel tracks. When they met, the train from Vancouver had travelled 60 km farther than the train from Kamloops. How far from Vancouver did they meet, and at what speed did each train travel?

How would you invest $10000, part at 8.5% and part at 11%, so that in the first year the interest from the 8.5% investment will be 100 more than twice the interest from the 11% investment.
Word Problems For Set # 2

Find a number such that when four times the number is added to twice its square the result is 96.

Nine trucks, some carrying 10 t loads and the other 6 t loads, are required to move 70 t of earth. How many of each are required?

The length of a rectangle is 2 cm greater than twice its width. The area is 60 square centimetres. Find its dimensions.

An estate valued at $29460 is to be divided among the deceased wife and three children. Each child is to receive one half as much as the wife. How much does each receive?

A number of dimes and quarters have the total value of $19.75. If there are 5 fewer quarters than twice the number of dimes, find the number of dimes and the number of quarters.

A store received a shipment of 29 pens invoiced at $78. The pens were of 3 types valued at $10, $2 and 50 cents. If there were twice as many pens at 50 cents as there were of $10, how many many pens were there of each kind.

It takes James 12 hours to drive from Vancouver to Williams Lake and back. The distance going one way is 286 km. If James’s rate going was 8 km per hour faster than his rate on the return trip, find his average speed in each direction.

If the train to Seattle travelled 10 km per hour faster than the train going to Vancouver, it would take 2 hours less to travel the 315 km one way. How many hours does it take to travel each way, and what is the speed of each train.
From an automatic coffee maker a person can get a cup of coffee with cream and sugar for 25 cents and a cup of coffee without cream and sugar for 20 cents. At the end of the day there was $8.45 in the machine and 36 cups have been used. How many cups of coffee with cream and sugar were sold.

One kind of chocolate sells for $2.50 a kilogram. A different sort of chocolate sells for $5.00 a kilogram. What quantities of each kind of candy should be used to make up a 100 kg mixture to sell for $4.00 a kilogram?

Divide 84 into 4 parts, so that the first is to the second as 2 to 3. The second to the third is 3 to 4 and the third to the fourth as 4 to 5. What are the numbers?

If you decided to borrow $1000 from the bank so you may buy a car, how much money will you owe the bank after 3 years if you made no payments during that time and the bank loans at 24% interest compounded annually.

The number of words in a child's vocabulary is a function of the child's age. A formula for the size of the vocabularies of typical children between the ages of 20 months and 50 months is \( N = 60A - 900 \), where \( A \) is the child's age in months and \( N \) is the number of words that the child uses correctly.

a) Find the age of a child having a vocabulary of 720 words
b) Find the number of words of a child who is 49 months old.

The three most populous countries of the world are China, India and Soviet Union, with a combined population of 1650 million people. Two hundred million more people live in China than in India, and the combined population of India and the Soviet Union is 50 million more than that of China. How many people live in each country?

It took Bettina 45 minutes to go 6 km down Taylor's River in a rowboat and it took her 1 and 1/2 hours to return. What was the speed of Bettina's boat in still water and what was the speed of the current
Word Problems For Set # 3

John has $83 in one, five and ten dollar bills. He has just as many one dollar bills as he has five and ten put together. If he has 16 bills altogether, how many of each denomination does he have?

Divide 20 into two numbers such that when the larger number is divided by 3 and the smaller number is divided by 4 their quotient added together is equal to 6.

The sum of the length, width and height of a rectangular box is 75 centimetres. The length is twice the sum of the width and height. Twice the width exceeds the height by 5 cm. Find the dimensions of the box.

The sum of the squares of 3 consecutive integers is 77. Find the integers.

For a rock concert, 8000 tickets were sold. Some sold for $7 and the rest for $4. If the total receipts were $41000, how many tickets of each kind were sold?

Nat borrowed $2100 for his college tuition. Part of it he borrowed from a special student fund at 5% annual interest. The rest he borrowed from the bank at 6.5% annual interest. If the total annual interest is $114, how much did he borrow from each source?

On a motor trip of 260 km, Sam drove part of the way at 70 km/h and the remainder at 50 km/h. If the total trip took 4 hours, how far did he drive at each rate.

If a ball rebounds to 90% of its previous height on each bounce and is dropped from a balcony 12 metres above the sidewalk, how far will it rebound after it has hit the ground for the 4th time?
To accommodate its members who were attending a convention, a society hired space in a hotel for $360. When 6 members could not attend, each member had to be taxed $2.00 extra to provide the $360. How many members attended?

A train leaves Calgary travelling East at 40 km/h. Two hours later, another train leaves Calgary travelling East on a parallel track at 50 km/h. How far from Calgary will the trains meet?

A photographer uses 2 types of developer solutions. One type is a 5% solution and the other is a 20% solution. For a particular job, she requires 30 litres of a 15% solution. How much of each should she mix?

Mary weighs three more kilograms than Jane, and together they weigh 16 kilograms less than the center on the football team who weighs 213 kilograms. How much does each girl weigh?
Appendix C - Word Problems from the Posttest.
Word Problems For Posttest

Problem 1:
In a football game, the Lions scored 2 points less than twice the number of points scored by The Tigercats. If 73 points were scored by the 2 teams, how many points did each team score?

Problem 2:
On a certain freeway, safety inspectors are supposed to spot check an average of 80 trucks per day. So far 65, 82, 85, and 73 trucks have been inspected on four successive days. How many trucks must be inspected on the fifth day to make an average of 80 trucks per day?

Problem 3:
The length of a page in a book is 2 cm greater than the width of the page. A book designer finds that if the length is increased by 2 cm and the width by 1 cm, the area of the page is increased by 19 square cm. What are the dimensions of the original page?

Problem 4:
An investment fund has $3000 more invested at 4% per year than it does at 5%. The interest on the amount invested at 4% is $30 per year greater than the annual interest on the amount invested at 5%. How much does the fund have invested at each rate?

Problem 5:
Mr. Egbert had driven 30 km at a constant speed, but found that he had to increase his speed by 30 km/h in order to cover the last 45 km in time to make an appointment. If his total travelling time was 1 hour, what was his original rate?

Problem 6:
Two numbers are in the ratio of 6:11. If the first number is decreased by four and the second increased by 6, the resulting numbers are in the ratio of 4:9. Find the original numbers.

Problem 7:
A 100 kg mixture of peanuts contains peanuts of 2 different kinds, one priced at $2 per kg and the other at $2.40 per kg. If the mixture is priced at $2.08 per kg, how many kilograms of each kind of peanuts does it contain?
Problem 8:
Jeff bought 5 jawbreakers and 10 bubble gum for $1.60. A jawbreaker and a bubble together cost 29 cents. How much did Jeff pay for each?

Problem 9:
It takes Jack 1 hour longer to walk his 6 km paper route than it does to ride his bicycle over the route. If he averages 3 km/h more riding the bicycle than walking, what is his rate walking?

Problem 10:
Two girls were selling candy. They had a $1.07 in change to begin with. Their first customer said that before he could buy anything, he needed change for half a dollar (a 50 cents coin). One of the girls looked into the change box and said they didn't have the change. The customer asked if they had any change for a quarter; the reply was no. The customer asked if they had change for a dime; the answer was no again. The girls said they had 7 coins in all but could not change a nickel either. What were the coins that the girls had?
Appendix D - Word Problems from the Think-aloud Interview.
Word Problems For Think-aloud.

Problem 1:
Roger has 6 times as many dimes as nickels and 3 times as many pennies as nickels. If he has $17, how many coins of each does he have?

Problem 2:
A mother took her 3 children on an airplane flight. Her ticket cost $2 more than twice each of the children's. If the total cost of the tickets was $203.25, find the mothers fare and the fare for each of her children.

Problem 3:
Mrs. Deharty drove 90 km one way to visit her sister. She averaged 15 km/h more on the return trip than she did on the trip going. If her total travel time was 3 and 1/2 hours, what was her rate on the return trip?

Problem 4:
Mr. Ulrich invested twice as much money at 5% per year as he did at 4% per year. How much did he invest at each rate if his annual return is $168.

Problem 5:
A mother is 3 times as old as her daughter. In 11 years she will be just twice as old as her daughter. How old is each now?

Problem 6:
The Employees Savings Plan at the MMC Company wants an annual income equal to $500 from an investment of $9000. They plan to invest part of the money at 5% and the remaining amount at 6%. How much should they invest at each?
Appendix E - Instructions for the Think-aloud Interview.
Instructions

The purpose of this interview is to obtain some understanding of the kind of thoughts that pass through your head as you solve math word problems. This is for my own research and has nothing to do with your grades at the end of the year.

What I am asking you to do is solve 6 problems altogether. The first one is a trial problem so you may get used to solving problems and think aloud at the same time. The rest of the problems will be recorded on an audio tape which will later be analyzed.

It is important that you say whatever it is that is going through your mind, whether you are going to use it or not for solving the problem.

It is important that you understand that what I am interested in is how you go about solving a problem rather than in your solution. Please do not ask if any of your work is correct until you have completed the interview.
Appendix E

Since other students will be participating in these interviews, please do not discuss the problems or interview with anyone.
Appendix F - The Coding System.
The Coding System

The coding form (on next page) is made up of twenty-two heuristic processes. The following is a dictionary to the heuristic processes used in this study. A check was marked every time one of the following processes took place.

1) **Rereads** - rereads all or part of the problem.
2) **Own words** - uses his or her own words to understand the problem.
3) **Clarifies data** - interprets to him or herself specific part(s) of the problem that constitute data.
4) **Recalls related problem** - recalls a problem which requires similar strategies in order to be solved.
5) **Recalls problem type** - recalls a similar type of problem.
6) **Draws table/diagram** - sets up a table, a diagram or any other similar kind of visual representation.
7) **Modify table/diagram** - modifies the existing table or diagram.
8) **Identify variable** - identifies which component of the problem needs to be the unknown.
Appendix F

9) **Identify relevant data/concept** - identifies and understands a key component or concept of the problem (somewhat close to insight/bright idea).

10) **Identify theorem** - identifies a theorem, for example: Interest = Principle * Rate * Time \( (I = PRT) \) or Distance = Rate * Time \( (D = R*T) \).

11) **Divide problem into subproblems** - decomposes problem into smaller subproblems.

12) **Make connection** - is a deductive process. When a connection is made between two or more components of the problem. For example, if the problem states that there are three times as many pennies as nickels and the student identifies the amount of nickel as \( X \) and the amount of pennies as \( 3X \) than a connection between the components has been made.

13) **Unable to make connection** - student is temporarily unable to continue.

14) **Works towards a goal or subgoal** - when an equation or part of an equation is written. When the student states that a component and a component equals or leads to a solution or part of the solution.

15) **Searches for a pattern** - tries to find a pattern, symmetry or make generalizations.

16) **Reasons deductively** - is a conditional deduction. If....then....
17) **Insight/bright idea** - when unable to proceed and suddenly an idea arrives. When a sudden realization of what needs to be done to arrive to the solution.

18) **Trial & error/guess** - a random entry of a number.

19) **Estimate/successive approximation** -

20) **Questions approach** - questions the direction in which she or he is going in in order to solve the problem.

21) **Changes approach/another method** - realizing that the direction is incorrect and will not lead to the desired solution.

22) **Checks solution** - checks by placing the solution in the equation (computer-as-calculator group) or checking the formulas again (spreadsheet group).
<table>
<thead>
<tr>
<th>Activity</th>
<th>Score</th>
</tr>
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<tbody>
<tr>
<td>Rereads</td>
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<tr>
<td>Own words</td>
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<tr>
<td>Clarifies data</td>
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<td>Recalls related problem</td>
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<tr>
<td>Recalls problem type</td>
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<tr>
<td>Draws table/diagram</td>
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<td>Modify table/diagram</td>
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<td>Identify variable</td>
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<td>Identify relevant data/concept</td>
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<td>Identify theorem</td>
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<td>Divides problem into subproblems</td>
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<td>Makes connection</td>
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<td>Unable to make connection</td>
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<td>Works toward goal/subgoal</td>
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<td>Searches for a pattern</td>
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<td>Reasons deductively</td>
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<tr>
<td>Checks the solution</td>
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</table>

Coding form for the analysis of protocols
Appendix G - The Four Steps of Problem Solving.
The Four Steps of Problem Solving

The FOUR steps of problem solving which are described below will help you become a better problem solver. Read carefully each step and when solving a problem follow the steps and questions where it’s applicable.

STEP 1: UNDERSTANDING THE PROBLEM:

a) Read the problem carefully.
b) Restate the problem in your own words.
c) Simplify the problem.
d) Separate the problem into component parts.
e) List the given information and questions asked. Write down any information needed for solving the problem.

STEP 2: DEVISING A PLAN TO SOLVE THE PROBLEM:

a) Have you seen a similar problem before?
b) Determine which is the unknown.
c) Find the relationships between all the components of the question, those that are known and those which are unknown.
d) Try to make a reasonable estimate.
e) Make sure you have seen and understood ALL the components of the question.
f) Decompose the problem into subproblems. Tackle it in small chunks.
g) If you cannot solve the problem, think of a similar problem which has a different twist to it.

STEP 3: CARRYING OUT YOUR PLAN:

a) Devise a solution plan and carry it out, step by step.
b) Make sure each step is correct and that it is the step you wanted to do.
STEP 4: LOOKING BACK:

a) Check your result.
b) Does it make sense?
Appendix H - The Questionnaire.
The Questionnaire

THIS QUESTIONNAIRE WILL HELP ME UNDERSTAND BETTER WHAT YOU THINK OF THE WAY YOU HAVE BEEN SOLVING WORD PROBLEMS FOR THE PAST 6 WEEKS. PLEASE MAKE WHAT EVER REMARK YOU FEEL IS NECESSARY.

1) Having used the spreadsheet/computer, would you use it again to solve word problems?

[ ] Yes
[ ] No

2) If you had an unlimited access to a computer, would you use the spreadsheet/computer to help you solve math problems?

[ ] Yes
[ ] No
[ ] I would consider it.

3) If you had to 'hassle' to get computer time, would you make the effort to use the spreadsheet/computer to help you solve math problems.

[ ] Yes
[ ] No
[ ] I would consider it.

4) Did you enjoy using the spreadsheet/computer to solve word problems?

[ ] Yes
[ ] No
[ ] Sometimes
5) Has using the spreadsheet/computer made you aware of different strategies for solving word problems? Please elaborate.

[ ] Yes
[ ] No
[ ] A bit

6) Do you think you would be able to use the strategies without the computer? Please elaborate.

[ ] Yes
[ ] No
[ ] A little bit

7) Please make any additional comment you would like to make.
Appendix I - Open-ended Responses from the Questionnaire.
Appendix I

Spreadsheet Group

Barb:

5) You can see different ways for solving problems. It can help you find the easiest way to solve a problem, rather than having to work it out the most difficult way.

6) With the computer it does all the work. If you did it by hand - you'd have a lot more calculating to do which may be a bit more work.

7) Using the spreadsheet helps me organize my work better, putting all the information together.

Anastasia:

5) It has shown me ways of using tables for solving problems. It makes it easier to solve and understand the problem once you know how to set it up.

6) It depends on the strategies used, some of the tables are harder to use because they take a lot of time, especially using variables rather than "C124xD125" and having it pop out.
7) It was great using the spreadsheet. It made the work a lot more fun and interesting. It’s also easier to understand some of the more difficult questions.

Mona Jean:

5) The spreadsheet has made me more aware of using different variables to solve problems. For example, in the DRT I realize that to find rate I can divide D by T.

6) I think it’s confusing taking it off the computer and putting it on paper, because the computer can do many transactions at once and trying to set up the chart is difficult.

7) I enjoyed the program and would not hesitate to do it again.

Jon:

5) a) I like the spreadsheet and it helped me solve the problems, so I would like to use it more often for word problems.

    b) I would use it for most word problems, but for others, paper and pencil and calculator is faster.

    c) On the spreadsheet it is a lot easier to show the relationships between the variables. When working on paper I prefer simultaneous equations.
Appendix I

6) As in 5

7) I am not a very good problem solver and the spreadsheet has helped me quite a bit I don’t think I would have solved some of the problems without it.

Amanda:

5) I never thought of using a variable that would change with the other numbers. On paper it’s a bit more difficult. But when I do math problems on paper I won’t see the ‘normal’ ways I used to right away. I will think about the new ways I know first, even though they are difficult to do on paper.

6) It is hard to do them on paper without the computer, but I think I would be able to use them a bit, but not much. A calculator would certainly be necessary.

7) Using the spreadsheet was mostly fun and it was interesting to see new ways of solving math problems.

Tracey:

5) The spreadsheet works like a chart and I don’t usually use charts. It’s helped me to organize my work and my thoughts when solving word problems.
6) It would take longer in some cases and other methods might work better, but by using the calculator and making reasonable guesses it would still certainly help to solve a problem. I have used a spreadsheet style setup in some of my in class math problems since learning how it works.

7) I think that using the spreadsheet is a good way to get people to be more organized when solving math problems. Its quite easy to use, but if you're unorganized it doesn't work at all.

Tim:

5) I have never really used the chart to solve problems, but having used the spreadsheet I can see the advantages.

6) I would be able to use the chart without the computer, but the best part about the spreadsheet is being able to use trial and error. This takes much too long without the computer.

Craig:

5) The spreadsheet helps me to find an easy variable and come to conclusion more quickly than if I were using pencil paper and calculator.
6) If I were to try and use the strategies without a computer as I do with the spreadsheet, it would take a long time and a lot of space. The spreadsheet is a very efficient way of solving problems.

Danielle:

5) Yes it has made me aware of different strategies because now I understand better how to get equations from word problems and how to solve them using different formulas.

6) Now I would be able to use them without the computer because I understand what I am actually doing when I solve the equation instead of just having to solve it and not understand what I am doing.

7) When entering the Math 10E course I was not prepared as much as the others in my class and word problems are definitively my most difficult areas in Math. I enjoyed using the spreadsheet and now understand better how to use the equations and get the equations from the word problems. I am glad I had the chance to take this added course with the spreadsheet. I would definitely recommend that it be introduced into other programs like ours and even in regular and core math.
Appendix I

Paul:

5) It has taught me how to set up word problems and how to sort out the known facts. I think I could solve problems with the spreadsheet that I couldn't solve on paper and especially a lot faster. I think it's great and I would strongly prefer it to paper. It is also easier to edit and add in things.

7) This has helped me set up equations in a much better way and understanding than before. I would have to say that I have learned many new strategies with the spreadsheet. Now that I have learned most of those strategies, I am quite sure I can do most of them on paper. But the spreadsheet cuts down a lot of the time, working out, and room for error that I find on paper. All in all I really liked using the spreadsheet and I feel it would be a good thing for students to be able to use it on a regular basis.

Brenda:

5) It helped me set up the problems better

7) Doing the spreadsheet program has helped me to understand word problems better. I always had real trouble with them before. I also can't concentrate for too long and get discouraged easily. The computer is
fun for me to work on so it helped me to work longer. I also like the way you get to \textquote{estimate} the answer and the computer does all the workk for you. I wish we could keep doing these things every week maybe i would help my math in other areas too. It was as fun as you can make math get.

Khai:

5) Some things you can only see on the spreadsheet because you can lay it all out in front of you without being confused by the complicated equations

6) If you thought about it as if you were doing it on the spreadsheet, some of the strategies may come to mind. Actually, I have thought about what I would have done on the computer when I was involved in tough situations

James Vipond

5) The spreadsheet lets me try many values in the equation

6) The computer would be easier to use, and it has a better way of me understanding what it is doing
Appendix I

7) The spreadsheet has helped me with classroom work very much. It has helped me to organize my thoughts and type them into the computer.

Computer Group

Mike:

5) All the computer did was show me the question and the computer was like my calculator

6) The computer is not a very good calculator. I like my calculator better.

7) I have a computer at home but do not have a program like the spreadsheet. If I had it I would use it for sure.

Bruce:

7) I enjoyed using the computer during the course and would like to use them again in the future.

Jay:

7) Mainly, all the computer has been doing for me is calculating basic problems. It is useful to have the questions printed on a screen and work with, but other than that, it has just been a calculator.
Appendix I

Kam:

5) It is just like a calculator

Beth:

5) It's just like a calculator but calculators are faster to use.

6) I used the same strategies on the computer as I did with my calculator.

7) Using the computer was more fun than calculator because it is the first time I have used it like this. I found that it took longer to type the equations than pushing buttons on the calculator.

Patrick:

5) I could have done all the calculations using a calculator

6) Yes the computer is just an expensive calculator. I would do just as well with a small calculator.