INSTITUTE OF EDUCATION

"THE USE OF SPREADSHEETS AS A TOOL FOR THE DEVELOPMENT OF PROBLEM SOLVING SKILLS IN THE MATHEMATICS CURRICULUM IN A PRIMARY SCHOOL IN CYPRUS"

"Each problem that I solved became a rule which served afterwards to solve other problems. "
Rene Descartes (1596-1650), "Discours de la Methode"

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ABSTRACT

The purpose of this research project is to examine the use of spreadsheets for the development of problem solving skills in primary school pupils. This study is based on the notion that advanced skills of comprehension, reasoning, composition, and experimentation are acquired not through the transmission of facts but through the learner's interaction with content. This constructivist view of learning calls for teaching basic skills within authentic contexts for modelling thought processes.

To gather the information I needed I worked for three months with a group of 12 pupils (six boys and six girls). A pre-test, a post-test and a post post-test one year later were used to gather quantitative data emerge from the research while I was taking part as a participant observer to record the qualitative data from the research.

The statistical analysis was carried out by SPSS-X. Percentages, means, standard deviations and medians were used to illustrate the variables. The Kolmogorov-Smirnov test was used for the Inferential Statistical Analysis.

The main findings of my research that emerged from the tests the pupils undertake and from my observations during the lessons are:

Regarding progress in problem solving ability: Pupils have increased their abilities in problem solving after using a spreadsheet to solve a series of problems. Regarding progress in problem solving ability after one year: Pupils did not increase or decrease their ability in problem solving as emerge from the post post-test. There were no problems of communication between the pupils during their work in the groups while collaborative work enabled pupils to apply facts and skills already acquired; encourage discussion and investigative activity to show that mathematics can be useful, meaningful and valuable. Teacher' s work was more demanding with a major change in his role, from a knowledge dispenser to a facilitator.

It is argued that there is an implicit need for curriculum change with the use of problem solving as a cross curriculum object and further, there are implications for the implementation of a general use of computers in primary education.

CHAPTER 1: BACKGROUND

The purpose of this research project is to examine the use of spreadsheets for the development of problem solving skills in primary school pupils. The significance of the research is twofold: first, the use of computers as a means of cross-curricular teaching rather than as a curriculum subject is especially important in primary schools; second, problem solving is at the heart of the mathematics curriculum. The significance is societal as well as educational. The combination of problem solving and instructional technology in a co-operative - learning setting can be critical to the development of a skilled twenty-first-century work force. Pupils should be prepared for a future in which the computer is used as an analytical tool rather than merely as a vehicle to test the accuracy of programming skills or for solving simplistic problems using long and complicated numerical values (Sgroi, 1992). As mathematics education adapts to the needs of a changing society, the use of technology becomes increasingly important. "Technology can play a valuable role in developing problem - solving capabilities in pupils by freeing them from tedious computations. Thus, higher level-thinking skills can be emphasised" (Hoeffner et al., 1993, p. 52).

The computer is a rich and complex tool that is increasingly within the financial reach of schools. Like any educational tool, it comes with inherent advantages and disadvantages. It is more appropriate for some uses than others. It depends on the human qualities and aspirations for its effectiveness.

Research may be operationalised at many levels. In this study, data will be gathered at two levels: the pupils and the teachers. Hopkins (1993) supports the idea that when

teachers themselves undertake research in their classrooms it is very beneficial because it is a way of improving practice, it enhances their teaching or their colleagues' teaching and they become more autonomous in professional judgement. "Teachers are too often the servants of heads, advisers, researchers, textbooks, curriculum developers, examination boards or the Department of Education" (p. 4).

The introduction of computers in Primary Education is an innovation for the Cyprus Educational System, and within this content, as a software application, spreadsheets can be used in the teaching of mathematics and in the developing of higher thinking skills like problem solving.

If effective learning can be shown from the use of spreadsheets, there may be new opportunities for the teaching of mathematics. It will help teachers to clarify the concept of problem solving and support their teaching. The use of spreadsheets can be incorporated into the mathematics curriculum, with the creation of instructional methods and materials for using spreadsheets for problem solving. On the other hand, poor results will force us to review the use of computers in primary education. In addition, an evaluation of the effectiveness of the program will create more questions for further research.

I. Aim

The purpose of the research is to examine through case study the role of spreadsheets in developing pupils' problem solving skills in primary schools.

II. Research Questions

The study will concentrate on a number of important factors associated with the following questions, amended from Newhouse and Oliver (1989):

1. **Do spreadsheets as a Computer Assisted Instruction application improve learning and teaching in problem solving activities?**

2. **In what ways do spreadsheets as a Computer Assisted Instruction application influence pupils' achievement in solving problems?**

3. **Are there variations in the effectiveness of Spreadsheets as a Computer Assisted Instruction application among different types of pupils?**

III. Methods

The case study will be conducted in my classroom with twelve pupils (age 10 to 11 years old). The project will rely heavily upon observations of the pupils and personal notes. Analysis will be made of pupils' achievement in problem solving before starting the project, at the end of the project both on problem solving and on using spreadsheets for problem solving.

The findings will be discussed in relation to the implications for the use of spreadsheets in primary schools, the problems in introducing them, and the training needs of teachers. They will also be discussed in relation to the contribution of spreadsheets to achieving the objectives of the mathematics curriculum in Cypriot primary schools.

CHAPTER 2: REVIEW OF THE LITERATURE

I. Problem Solving

Pólya (1887-1985), the pioneer of problem solving techniques - the heuristic strategies - in an article presented in 1949 and reprinted in "The 1980 Yearbook" of the National Council of Teachers of Mathematics in the United States, states that

> Intelligence is essentially the ability to solve problems: every day problems, personal problems, social problems, scientific problems, puzzles, all sorts of problems. The pupil develops his intelligence by using it, he learns to do problems by doing them (cited in Krulik, 1980, pp. 1-2).

Mathematics is hard. Problem solving is considered to be of the most difficult mathematics topic to teach and learn. "Teachers have been concerned about their pupils' inability to solve problems since problems first appeared in math textbooks" (Randall and Frank, 1982, p. 1). The development of problem solving ability must be the focus of mathematics instruction (Shufelt & Smart, 1983) and should direct the efforts of mathematics educators. " Curricula in several countries are in the process of being modified to incorporate explicit consideration of the nature of general problem solving strategies" (Lawson, 1990, p. 403). Gadanides (1988) suggests that in any model of mathematics teaching, problem solving is a major area of emphasis together with facts and skills, and understanding.

When teaching mathematics at any level, an experience most teachers have, is that pupils do not know how to solve problems: Although they know enough mathematics, they lack the most basic mathematical skills and abilities for problem solving. In the process of

problem solving what is considered important are "the methods, procedures, strategies, and heuristics that pupils use in solving problems" (Branca, cited in Krulik, 1980, p. 4) and not the answer a pupil gives to a problem. A number of studies on how to develop methods of teaching problem solving and strategies for problem solving have been developed and are presented in the following paragraphs.

A. What is a problem?

In order to analyse problem solving we have to consider first what a problem is. Randall and Frank (1982), define the problem as a task for which:

> The person confronting it wants or needs to find a solution.
> The person has no readily available procedure for finding the solution.
> The person must make an attempt to find a solution (p. 5).

Also, a problem for Brannan and Schaaf (1983, p. 43)

> ... is a situation in which an individual or group accepts the challenge of performing a task for which there is no immediately obvious way to determine a solution. Frequently, the problem can be approached in many ways. Occasionally, the resulting investigations are non-productive. Sometimes they are so productive that they lead to many different solutions or suggest more problems than they solve.

Another definition of mathematical problem is given by House et al. (1983, p. 10) is,

> ...a mathematical problem is a situation that involves a goal to be achieved, has obstacles to reaching that goal, and requires deliberation, since no known algorithm is available to solve it. The situation is usually quantitative or requires mathematical techniques for its solution, and someone must accept it as a problem before it can be called a problem.

Gadanides (1988, p. 22) argues that problem solving should be "incorporated and integrated in everyday classroom learning environments as much as possible". Krulik (1981, p. 191) states that, what makes a problem differ from an exercise is that "a problem is not a problem at all if it can easily be solved by following a given model or by merely applying a series of basic rules that have previously been learned".

B. Types of problems

There are three types of problems found in elementary school mathematics curriculum (LeBlanc et al., 1980; Randall et al., 1987; Randall and Frank, 1982):

1. Standard textbook problems: one-step problems or multiple-step problems.
2. Process problems.
3. Applied problems.

Standard textbook problems can be solved by direct application of an algorithm; the task is to choose which operation(s) or algorithms are appropriate for solving the problem. The purposes of these problems are "improving the recall of basic facts, strengthening skills with the fundamental operations algorithms, and reinforcing the relationship between the operations and their applications in real -world situations" (LeBlanc et. al, 1980, p. 105).

For example:

> ***Joe went to the store to buy 3 cartons of Coke. If each carton contains 6 bottles, how many bottles of Coke did Joe buy? (LeBlanc et al., 1980, p. 105).***

Process problems require the use of one or more strategies. This type of problem "stresses the process of obtaining the solution, rather than the solution itself" (LeBlanc et al., 1980, p. 105). Choosing an operation(s) or an algorithm cannot solve such problems.

For example:

> ***A backgammon club held a tournament for its 7 best members. If every member played one game against each other member, how many games were played?***

Applied problems require the pupil to collect data outside the problem statement.

For example:

> ***You and a friend decide to operate a sandwich stand in the school fair. You need to decide what to charge for each sandwich.***

A teacher who is aware of the various problem types is more able to make decisions concerning a good preparation of his or her mathematics lesson. In preparing the objectives of every unit, the inclusion of a problem every day, choosing one from each group will be effective. Process problems require thinking processes like planning, guessing, estimating, and looking for patterns. A teacher can make his or her personal collection of problems and present a problem every day, at the beginning or at the last ten minutes of the lesson calling this activity "Problem of the day". Drawings showing the four-step method, and signs with the names of strategies that have been used for solving these problems, together with the collection of problems presented to the pupils can make a good learning atmosphere in the classroom.

C. <u>What makes a problem difficult to solve?</u>

What makes a problem difficult to solve depends on a number of factors; "environmental and personal factors, affective factors, and cognitive factors" (Randall and Frank, 1982, p. 12). Randall and Frank (1982) list seven factors that have the most influence on problem solving:

1. Complexity of the problem statement: The complexity of the syntax, the amount of information, given the number of conditions and variables, and the mathematical content.

2. Methods of problem presentation and representation: The manner the problem is posed and the mental picture the solver forms.

3. Problem solver' s familiarity with acceptable solution procedures: A pupil can more easily solve a problem if he or she has used that procedure before.

4. Misleading incorrect solutions or solution procedures: Of the way a problem is posed or of nature of the problem, a misleading solution or procedure is suggested. For example:

> ***Andreas and Maria, have together 20 colour pencils. Maria has 6 colour pencils more. How many pencils does Maria have and how many pencils does Andreas have?***

5. Difficulty in locating reachable sub goals: Pupils do not know how to get started or what to do first.

6. Constraints arising from misconceptions or misunderstandings of information given in a problem: Misconceptions and misunderstandings often change the meaning of the problem by sometimes adding constraints?

7. Affective factors associated with the problem solver' s reaction to the problem: Lack of interest and motivation, high stress or anxiety, lack of perseverance and desire to get an answer quickly.

Other factors that make Standard Textbook Problems difficult to be solved according to LeBlanc et al. (1980) are, the more the complex the algorithm, the more the difficult the problem and the number of steps required solving the problems. Some of the difficulties that can arise while working on Process Problems are (LeBlanc et al., 1980):

1. The number of conditions that must be satisfied simultaneously.

2. The complexity of each condition.

3. The type of strategy required solving the problem.

D. Problem solving steps and problem solving strategies

Problem solving of any kind, whether it involves mathematics, medicine, business or family life, is a learned and practised skill. By developing their problem solving skills, pupils will come to realise the potential usefulness of mathematics in their lives. Much of the work on problem solving steps is based on George Pólya' s (1957) work with some variations (Gadanides, 1988; Kersh & McDonald, 1991). Pólya, in his famous book 'How to Solve it', suggested the following four phases for solving a problem (In **Appendix E** are cited the classic heuristics of George Pólya):

Understand the problem: See clearly what is required. Find out what the problem means.

Devise a plan: Check how the data are connected and how they are related to the unknown to make a plan. Choose the strategy or strategies that will help for solving the problem.

Carry out the plan: Pupils work through the problem until they find the answer to the question.

Look back: Review and examine the solution to see if it meets the conditions stated in the problem.

If a pupil leaves out a step then she or he will not be able to solve the problem correctly. Also, pupils have to check each step and perhaps see this four-step method as a circle rather than as an algorithm where you move from one step to another without looking

back. A good way to understand those four phases is to examine the role of the teacher and the role of the pupil during each phase. Teachers play a critical role in helping pupils during problem solving. But, what are these specific actions, and behaviours? In general, a teacher' s effort in mathematics must be the development of pupils' abilities to solve problems.

Phase 1: Understanding the problem

Pupils should understand the problem and have the 'desire' (Pólya, 1957; Randall & Frank, 1982) to approach the problem. They must understand the words and phrases used and what is happening in the problem; identify and determine necessary and unnecessary information. Pupils "may retell the story in their own words as a way of better understanding the problem. Pupils should eventually be trained to ask themselves questions when they are confronted with a problem" (Randall & Frank, 1982, p. 37). Teachers, on the other hand have to choose the problem so as not to be very easy or very difficult. Pólya (cited in Krulik, 1980) believes that a teacher "should set his pupils the right kind of problems: not too difficult and not too easy, natural and interesting challenging their curiosity, proportionate to their knowledge. He should also allow himself some time for presenting the problem appropriately" (p. 2). The problem must be stated verbally very clearly while the teacher asks questions to see whether his or her pupils understand the problem or help them to clarify it, like:

What is the unknown?

What are the data?

What is the condition?

Phase 2: Devising a plan

The teacher directs pupils' "attention to related problems and previously used strategies where possible" (Randall & Frank, 1982, p. 37). Pupils suggest their strategies that they share with the rest of the class.

Have you seen it before? Or have you seen the same problem in a slightly different form?

Do you know a related problem?

Do you know a theorem that could be useful?

Phase 3: Carrying out the plan

Pupils work through the problem on their own using the plan of phase two. If they have difficulties then, the teacher encourages them to go back, check if they truly understand the problem and re-check their plan using a different strategy.

Phase 4: Looking back

Pupils check the answer if it meets the conditions stated in the problem and that it answers the question. The teacher asks the pupils to share with the class the strategies they used to solve the problem so that they consolidate the knowledge gained from the solution and for developing pupils' ability for solving problems (Pólya, 1957; Randall & Frank, 1982).

Can you check the result?

Can you check the argument?

Randall and Frank (1982, p. 31) proposed the following goals for teaching problem solving based on the four-step method:

Pupils should be able to:

1. Develop the skills necessary to apply their mathematical understandings to recognise, identify, and formulate problems from given practical situations outside the domain of mathematics, as well as from relevant situations within the domain of mathematics. (Look at the situation.)

2. Develop skills in using problem analysis strategies and modelling techniques.

(Get to know the problem and decide what to do.)

3. Develop skills necessary to solve problems in all strands of the mathematics program. (Do it.)

4. Develop skills necessary to interpret or evaluate the solution in the original situation, or in an application to a new situation, of a generalisation. (Think about what is done.)

In Pólya' s four step method for problem solving, pupils have to decide in Phase 2, how to solve the problem. There is a number of problem solving strategies that pupils can use to solve a problem and reach the desired solution, as discussed in detail with examples from Hoogeboom and Goodnow (1987): 1. Act out or use objects 2. Make a picture or diagram 3. Use or make a table 4. Make an organised list 5. Guess and check 6. Work Backwards 7. Use or look for a pattern 8. Make it simpler 9. Use logical reasoning 10. Brainstorm.

Act out or use objects

> *Rico keeps his games on a shelf in his room. Sly Spy is in front of Chinese Checkers. His Chess game in on the left side of Sly Spy. Crazy Cards is between Chinese Checkers and Dominoes. Dominoes are behind the Beetles game. Where is each game on Rico's Shelf?*

Front of Shelf

From Hoogeboom and Goodnow (1987, p. T•31)

Make a picture or diagram

Jim is looking for friends to play softball. His friends all live on his side of the street. First he goes down the hill 4 houses to get to Lenny. Lenny lives in the first house on the block. Then Jim goes up the hill 6 houses to get to Raul. From here he goes down the hill 3 houses to find Terry. Next he goes up the hill 13 houses to get Renata. She lives in the last house on the block. How many houses are on Jim's side of the street in his block?

From Hoogeboom and Goodnow (1987, p. T•19)

Use or make a table

Ellen is 10 years old now and Cheryl is 15. A few years ago, when Cheryl was twice as old as Ellen, Cheryl taught Ellen how to swim. How old was Ellen when she learned to swim?

From Hoogeboom and Goodnow (1987, p. T•39)

Make an organised list

The people in the Land of Few make up their own telephone numbers. The only numerals they use are 2, 6, 7, and 8. Their telephone numbers are two digits long. This is what the telephone book looks like now:

Name	Telephone Number
Adams	*22*
Bears	*26*
Cricket	*27*
Dim	*28*

What other telephone numbers can be made by the people in the Land of Few?

From Hoogeboom and Goodnow (1987, p. T•15)

Guess and check

Zoobee has two kinds of flowers in his garden: Dandelions and tiger lilies. Zoobee planted only tiger lilies, but dandelions came up too. There are 51 flowers in Zoobee's garden, and there are more dandelions than tiger lilies. How many of the flowers are tiger lilies and how many are dandelions?

From Hoogeboom and Goodnow (1987, p. T•83)

Use or look for a pattern

Mona is wearing her magic cape again. The first time she wore it, she found 5 pennies in a crack of the sidewalk. The next time she wore it, she discovered 9 pennies under an old barrel. The third time she wore it, she found 13 pennies in some sand. The fourth time she wore it, she discovered 17 pennies under the bleaches in a ballpark. If Mona keeps finding pennies this way, how many will she find when she next wears her cape the eighth time?

From Hoogeboom and Goodnow (1987, p. T•49)

Work Backwards

Someone broke a bag of peanuts on Peep Street. Pigeons came from all over the city to feast on the peanuts. They ate lots of the nuts on Monday. They ate 2 fewer nuts on Tuesday than on Monday. They came back again on Wednesday, Thursday, and Friday. Each day they ate 2 fewer peanuts than the day before. On

Friday they cleaned up the last 4 peanuts. How many peanuts in all did the pigeons eat?

From Hoogeboom and Goodnow (1987, p. T•85)

Use logical reasoning

An old sneaker, a cup, a bottle, and a can fell off Drew's Dock and dropped to the bottom of the water. Along came a fish, a snail, a crab, and a worm that were looking for homes. The worm slithered into the bottle. The crab crawled into the sneaker. The fish would not go near the can. What did each sea animal choose as its home?

From Hoogeboom and Goodnow (1987, p. T•77)

Make it simpler

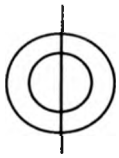
Desmond wins points by tossing rings at a number board. There are four numbers on the board: 1, 4, 5, and 7. Desmond gets to toss two rings on each round, and he never misses! He hits a number every time he tosses a ring. What are all the different ways Desmond could score points in each round? For example:

	First Ring	**Second Ring**
Round	**1**	**1**
Round	**1**	**4**

From Hoogeboom and Goodnow (1987, p. P•22)

Brainstorm

Ursula showed us this design and asked, "Can you draw this shape without picking up your pencil, without crossing a line, and without retracing a line?" How can you do it?



From Hoogeboom and Goodnow (1987, p. P•12)

Of course a pupil has to know something, to use it! The question is what is the right way for a teacher to present the problem solving strategies; whether there should be unit lessons presenting each strategy with examples and exercises to work with or should they be presented in everyday instruction. Brannan and Schaaf (1983, p. 43) after considering a number of studies, suggest that 'pupils become better problem solvers if they learn a variety of problem solving skills and have opportunities to apply the skills'.

On the other hand, House and Wallace et al. (1983, p. 10) suggest that "problem solving is the process of attacking such a problem" involving the "use of heuristics but not in a predictable manner, for if the heuristics could be prescribed in advance, they would themselves become algorithms and the problem would become an exercise" (p. 10). It follows that problem solving is not a skill to teach separately in mathematics lessons. Everyday instruction presents opportunities to present a heuristic strategy. By having a collection of problems that highlight different strategies, pupils work through the problems and the teacher focuses on the use of strategy and providing a general description of the strategy (Schoenfeld cited in Krulik, 1980).

E. Assessment of problem solving skills

The evaluation of a Standard textbook problem presents no problem. Since all that is asked is a simple answer, the only thing a teacher has to do is to check whether the pupil has the correct equation or gave the correct answer. But, the issue of assessment is different when a teacher has to evaluate Process Problems, when he or she has to evaluate not only the answer but also the process used to solve problem. During problem solving evaluation teachers are evaluating the skills involved in problem solving and the goals for teaching problem solving (Randall, Lester & O' Daffer, 1987). However, before discussing evaluation techniques, the goals to assess should be considered. Randall et al. (1987, p. 7) identified seven goals for teaching problem solving:

1. To develop ***pupils' thinking*** skills.
2. To develop pupils' abilities to ***select and use problem solving strategies***.
3. To develop ***helpful attitudes and beliefs*** about problem solving.
4. To develop pupils' abilities to ***use related knowledge***.
5. To develop pupils' abilities to ***monitor and evaluate their thinking*** and progress while solving problems.
6. To develop pupils' abilities to ***solve problems in co-operative learning situations***.
7. To develop pupils' abilities to ***find correct answers*** to a variety of types of problems.

1. Thinking Skills

During problem solving a number of thinking skills are involved like:

Understand/ formulate the question in a problem. The problem solver has to understand what is being asked in the problem and the relations between the question and the data given in the problem.

Understand the conditions and variables in the problem. The pupil develops a sense on how conditions and variables are related by making a model, a diagram or a picture.

Select or find the data needed to solve problems. The pupil has to be selective, that is to use relevant data and ignore non-relevant data.

Formulate sub-problems and select appropriate solution strategies to pursue. The problem solver must identify if there are multiple steps to be reached in the problem and select the appropriate strategy or strategies to be used

Correctly implement the solution strategy or strategies and solve sub-problems.

Give an answer in terms of the data in the problem. Give the answer using the correct units and/ or with a correct and complete answer.

Evaluate the reasonableness of the answer. After rereading the problem the pupil has to determine if the answer is logical or not, looking on the conditions and variables.

2. Select and use problem-solving strategies

Some of the strategies that can be used are:

a) Guess, check, revise
b) Make a table
c) Draw a picture
d) Look for a pattern
e) Act out the problem
f) Make an organised list
g) Use objects
h) Write an equation
i) Choose an operation(s)
j) Use logical reasoning
k) Solve a simpler problem
l) Work backward

3. Helpful attitudes and beliefs

Good attitudes and beliefs can help pupils' performance.

4. Use related knowledge

Related knowledge can be mathematical or might have to do with the context of the problem. Pupils can be taught how and when to use that knowledge.

5. Monitor and evaluate their thinking

Pupils should slow down periodically and reflect on what they are trying to do, what they have done, and what they still need to do.

6. Solve problems in co-operative learning situations

Accept the social skills developed in a co-operative learning situation, pupils learn also how to clarify their idea, evaluate someone else ideas.

7. Find correct answers

It is important after all for pupils to find the correct answer as motivation to go on with the next problem.

F. Problem solving in the Cyprus Primary Education Curriculum

Mathematics is one of the main subjects of the Cypriot National Curriculum, and both teachers and administrators emphasise its teaching and learning. The fact that the teaching of Mathematics covers 17 per cent of all school time, six teaching periods out of thirty-five, is evidence of this. Moreover, mathematical elements are incorporated in almost all other subjects such as Science and Geography. Problem solving is considered an integral part of all mathematics learning and not an isolated part of the mathematics program that will support the development of mathematical understanding.

The general scope of mathematical teaching in the Cyprus Primary Education, ages 6 to 11 years old, as stated clearly in the mathematics curriculum is:

a) To develop the mathematical thinking of the pupils, and

b) To help pupils capable to intimate and solve mathematical problems that are useful in everyday life and in sciences, as well as to appreciate the usefulness of Mathematics and enjoy the discipline thinking and harmony that exist in it (Ministry of Education and Culture, 1994, p. 93).

According to the curriculum document, problem solving pervades all areas of the Mathematics syllabus (Ministry of Education and Culture, 1994). Pupils should have frequent opportunities to formulate, grapple with, and solve complex problems that require a significant amount of effort. The 1994 Curriculum considers problem solving as the focus of mathematical instruction. Pupils use their knowledge and skills during problem solving while they develop their creativity (Kyriakidou, et al., 1995). Problem solving as a teaching instruction can help pupils to acquire mathematical concepts and make them able to communicate mathematically to describe everyday activities. The model, ***understand the problem - develop a plan - carry out the plan - go back and check the answer*** is proposed. Mathematical textbooks contain a variety of problems that can be solved by using a number of problem solving strategies. These strategies are introduced through solving different types of problems. There is no systematically ordered teaching of every strategy.

The General Aim of mathematics (Ministry of Education and Culture, 1994, p. 94) states clearly that, "pupils should be able to use a variety of strategies in the solving of mathematical problems" (p. 95). As such, for ages 10 to 11 years old, it proposes (p. 107) the use of the following problem solving steps and strategies:

construct pattern using objects, colours and numbers
draw a picture
make a table

select the appropriate operation (addition, subtraction, multiplication, division)
use of concrete objects for problem solving
use of logical thinking
guess and check
write the question, to an unfinished problem
write the correct mathematical sentence

Problem solving should not be considered as a stand-alone unit in the mathematics curriculum but rather as a cross - curricular skill. The new mathematical textbooks (published in 1995 and 1996) consider problem solving as an aim and as a means for teaching mathematics. Although, problem solving has a prime value in mathematics, standard textbooks (edited in 1986) being used in the Cyprus Primary Education, grades 3rd to 6th require mainly an algorithmic approach for solving problems, having all the problems cited at the end of every chapter.

The assessment of the problem solving skills can be done by observing the pupils if

they try to understand the problem and then try to solve the problem
they can find similarities between problems
recognise the symbols and terms used in the problem
where is possible they can solve the problem with more than one way
use of certain problem solving strategies (Kyriakidou, et al., 1995, p. 17)

Although, there are very good problems to help pupils develop problem solving skills, by personal observations, teachers prefer a solution given by solving a mathematical sentence. As a result, the pupil's task is to identify which operation or algorithm is appropriate for solving the problem.

For example, the following problem is a very regular exercise when doing fractions in the 5th and 6th Grades that can be used to broaden pupils' problem solving skills:

> *Andreas saved the $\frac{5}{8}$ of the money he needs to buy a bicycle. What is the price of the bicycle, if Andreas needs another £15?*

This problem gives to the teacher the opportunity to use the following diagram to help pupils solve the problem by posing questions like,

Suppose this rectangular represents the value of the bicycle, in how many pieces should I divide it to show the money Andreas has? (eight)

$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$

What do the shaded parts represent? (The money he has)

What is the value of each shaded part? (1/8)

What is the value of each un-shaded part? (1/8)

The rectangle represents the money he needs to buy the bicycle. The shaded parts the money he has. The rest 3/8 the money he needs, that is £15.

<u>Solution</u>: $\frac{1}{8}$ is equal to £5 pounds so $\frac{8}{8}$ are equal to £40 pounds

A research review from Suydam (cited in Curcio, 1987) identifies three trends in helping pupils become better problem solvers: "Experience practically always improves performance" (p. 99). Pupils by solving lots of similar problems are able to solve problems of a certain type but not solving other types of problems. A different method is to give them better problems. Usually these problems are at the end of each unit. Pupils

have to apply the knowledge they have acquired in that chapter to solve them. These problems are 'routine problems' (p. 100). By including 'non-routine' problems attention was given to strategies or heuristics. Pólya' s four-step method influence is evident and a number of researchers or pieces of research show that teaching problem solving strategies help pupils become better problem solvers.

II. Information Technology

When computers became available commercially, they were found only in educational institutes. They were used mainly in the engineering and the research departments of universities. Later, computer use in schools was in the field of computer programming. "The development of the microprocessor in 1974 and the subsequent creation of microcomputers was a turning point in the history of educational computing" (Newhouse & Oliver, 1989, p. 181).

A. Computers in education

Computing power is more available and affordable than ever before. Small business, education, and home, all over the world as well as teachers, parents and school systems moved to take advantage of this new phenomenon. PCs are simple machines that teachers and their pupils can use in the classroom as a tool to promote pupil learning within the regular curriculum. The use of computers as an instructional aid helped the popularity of computers in schools.

Computers are both a focus of study to become computer literate and an aid to learning and teaching. Pupils become computer literate, they know how computers work and what

they are used for. Yet, they can help pupils learn about anything and everything around and beyond school subjects preparing them to use tools they will need in their adult lives, for lifelong learning.

B. When to use computers in the classroom

Some persistent computer stereotypes need to be set straight according to Dublin et al (1994, p. 37):

> Computers are not 'drill and practice" machines.
> They do not serve much purpose if they are used just for "enrichment".
> They do not represent a new subject to teach, but rather a new tool to teach existing subjects.

Computers are problem -solving machines and need to be seen in schools as solutions to problems that naturally exist in the school environment. Some of the potential sources of computer solvable problems in schools are:

> The computer can be used to support learning activities that are difficult to perform in other ways.
>
> The computer may serve a role to address the needs of special groups of pupils, i.e. the handicapped, low ability, and those requiring extension activities.
>
> The computer can be used in many ways as stimulation and motivation for a range of other learning activities and situations.
>
> Computers can provide a rich variety of teaching strategies, accommodating to widely divergent learning styles, multiple intelligence, and special learning needs within classrooms.

In the hands of a teacher, computers are tools to accommodate and adapt to a number of different kinds of learners. With the right software, the computer can become a tool for

responding to the needs of pupils who do better when they can visualise the concrete manifestations of a mathematics operation or a pupil who needs more practice in the way to set up the solution to math word problems, or a pupil with a physical or learning disability who for example need shortcuts in keyboarding. Computers can provide pupils with learning disabilities or physical handicaps entry points to learning and communicating they have never before experienced in schools.

C. Computer Assisted Instruction

In Computer Assisted Instruction, computers are used for the solution of educational problems. They become part of an overall teaching strategy to enhance instruction and learning. There is an interaction of the learner with a direct instructional role. They are integrated into the curriculum and are not a separate curriculum themselves.

The two major characteristics of CAI are interaction and flexibility (Lockard, et al., 1994). "Pupils interact directly and continually with the computer, responding to prompts and questions, receiving feedback to whatever they have done. The computer becomes a private tutor" (Lockard, et al., 1994, p. 185) CAI have the flexibility to teach almost anything from "higher-order thought processes such as problem solving skills to the relatively simple cognitive learning usually associated with stimulus-response theory" (Lockard, et al., 1994, p. 185). These two crucial elements of CAI meet the diverse learning needs of individual pupils.

The four major forms of CAI share the same goal, e.g. to help pupils learn, drill and practice, tutorial, simulation, and problem solving (Erickson & Vonk, 1994; Lockard et al., 1994; Newhouse & Oliver, 1989):

Drill and Practice software does not teach any new concepts or ideas. It helps pupils "to review, remediate, rehearse, and practise. The software does not teach, but provides the opportunity to ensure understanding of concepts" (Erickson & Vonk, 1994, p. 67). Pupils remember and use information they have previously been taught. It provides pupils with problems to solve but it does not help to solve the problem. A principal criticism is that Drill and Practice software does not fully use the capabilities of the computers and all that it provides could be accomplished just as easily with pen and paper. Critics also "claim that they are often boring, very narrow in their pedagogical approach, drill all pupils regardless of their ability or level of functioning, interfere with desired remembering, and often provide undesirable negative feedback" (Lockard, et al., 1994, p. 189). "Good D&P software provides immediate and effective feedback to the pupils ... and can reduce unnecessary redundancy" (Erickson & Vonk, 1994, p. 67).

Tutorial Software is designed to teach new concepts and ideas. They present new and unfamiliar material to the pupils. They present information to facilitate pupils' learning. Two common uses of tutorial software are for reinforcement and remediation. They are the most commonly used software in schools.

"**Simulation software** is designed to approximate real-world experiences in a safe, controlled environment... and help pupils develop mental model" (Erickson & Vonk, 1994, p. 76).

Problem solving: The software gives the pupil a problem to solve and offer alternatives for solving it. They are open-ended while some programs try to teach pupils a process for

problem solving. Advocates of problem solving software assert that it contributes to enhancing pupils' skills. Critics of this believe that "any skills developed will indeed transfer is open to question" (Lockard, et al., 1994, p. 201). Research findings suggest that outcomes of CAI depend on many factors:

> CAI has shown positive achievement gains, learning in shorter periods of time than traditional instruction, longer retention of content learned, and a more positive attitude on the part of the pupil toward the learning process. These results are encouraging and provide support for the use of CAI in our classrooms. Much research is still needed to learn how best to apply the computer to instruction (Lockard, et al., 1994, p. 201).

D. Integrating Learning Systems

Integrated learning systems (ILS) are networked CAI systems that manage individualised instruction of curriculum material (mathematics, science, language arts, reading, and writing). ILSs differ from most stand-alone CAI in their use of a network (i.e., computer terminals are connected to a central computer) and in their more extensive pupil record-keeping capabilities. The systems are sold as packages, incorporating both the hardware and software for setting up a computer lab. ILSs are typically sold in sets of workstations. There are numerous systems on the market. Major producers in U.S. include Jostens Learning Corporation, WICAT Systems, and CCC and in U.K. Success Maker and GlobalMath.

The instructional software within ILSs is typically conventional CAI: instruction is organised into discrete content areas (mathematics, reading, etc.) and requires simple responses from pupils. ILSs are integrated to support "current class work with the teacher in control at which units are to be offered to pupils at any time" (NCET, 1996, p. 33)

A new trend in integrated learning systems is represented by ClassWorks, developed by Computer Networking Specialists. ClassWorks offers the school access to whatever variety of third-party software the teachers select, along with all the instructional management features associated with an ILS (Mageau, 1990).

ILS can be used for general reinforcement, to give extra practice to pupils in the lower ability range or to provide extension work for the more able. Another approach is where specific units are used to introduce a new topic. Here the pupils may be set tasks for revision or to give them the skills they need to embark on a particular topic; alternatively, teachers might use the ILS as a visual aid in their introduction of a new theme (NCET, 1996, p. 33).

Many pupils with special needs can access ILS. Many programs have spoken instruction and explanations that make ILS accessible to pupils that have problems with written words. They can hear the instruction as often as they want, in an adjustable sound level. Also, regarding the devices a variety of them are available for pupils with visual impairment.

Reports (NCET, 1996) in United Kingdom and in United States show that pupils using ILS have made improvements in learning attitudes. Furthermore, ILS has been found (NCET, 1994) to bring underachieving pupils to normal levels of attainment, especially in the area of basic skills. Many have also shown favourable attitudinal and behavioural changes, a greater sense of autonomy and added self-confidence. Many pupils benefit from not having to write by hand and from the wide variation of presentation in any one

session. Pupils like the privacy ILS affords them to make mistakes and correct them. ILS is also a powerful tool for the professional development of teachers. Moreover, teachers using ILS develop awareness of pupils' learning process.

E. The role of the teacher and the pupil

"Teachers and pupils have a variety of roles to play in the classroom which have implications for computer use. Computer technology permits the teacher to become more a manager of learning and permits pupils to become more involved in determining and evaluating their own learning" (Newhouse, et al., 1989, p. 81).

There is a new changed role that a teacher has to undertake. With teacher as a manager of learning there is a shift from the teacher-centred to the pupil-centred model. The teacher directs what and how the pupils learn whether this is by controlling the instruction or providing the learning situations. It involves, guidance, discipline, control at a distance, one-to-one interaction with pupils, managing equipment, setting the ground rules, presenting information, providing feedback and evaluation. "The teacher is a facilitator of co-operative learning by involving pupils in real problem solving situations" (Newhouse, et al., 1989, p. 80).

Raptis and Rapti (1997, p. 80) classified the teachers, researchers and those who are in the centres where decisions are taken concerning information technology into three categories:

1. Those who are in favour of the implementation of every new technology without examining in depth possible pedagogical limitations and consequences. They are in

favour of every technological evolution that they consider positive and beneficial for the progress of humanity.

2. Those who consider this innovation with scrutiny, they are against the use of computers for teaching and learning and are facing the new technology defensively with conservatism, overwhelming the influences on changing the way of our life, refusing even to try to become familiar to the system.

3. Finally, there those who support the implementation of the new technology in the school class for economical, socio-political and pedagogical reasons. They are aware of the danger of the computer becoming an instrument that controls and emphasise the role of the teacher in between the pupil and the computer.

On the other hand, pupils listen to their teacher, completing work the teacher has assigned, working with other pupils in small groups, acting on the teachers' instructions. Pupils need to develop skills in determining and assessing their own learning, in recording and evaluating their findings, have increased level of comprehension and concentration. They need to be able to interpret their findings and make decisions about directions for learning.

F. Models of implementation

Computer assisted instruction implementation requires changes in attitudes and classroom practices and for some teachers the development of some practical skills. These include computer operation skills and classroom management skills. The effectiveness of CAI software is dependent on the manner it is implemented, and in a great deal to the teacher, his or her skills and beliefs. There are four models of how to implement computers in a school (Newhouse et al., 1989; Dublin, P. et al., 1994). Three

models locate computers in the classroom; whole class model, one-to-one model and group work model. The fourth model locates computers in a computer lab.

The implementation of computers in education depends on many factors; the teachers, the pupils, the school building, the availability of funding (number of computers). In each model there is a different emphasis on the interaction between pupils, computer system and the teacher.

Whole class model

The computer can be placed at the back of the classroom where groups of two or three pupils can work, while the rest of the class is doing another activity. This computer centre helps in co-operative activities, together with the other centres in the classroom like the science centre, the reading centre, the art centre, etc.

Alternatively, the computer might be placed in the front of the classroom and with the appropriate device and software to be connected with a TV monitor. Teachers will use it more as presentational tool maintaining total control over the interaction. The application used must be part of the curriculum being addressed.

One-to-one model

The centre of interaction is between an individual pupil and the computer. The teacher is facilitating the interaction and has a reduced role. The computer replaces the teacher as instructor and controller. Each pupil needs access to a computer and appropriate software. Pupils are responsible for their interaction with the machine although this may be guided be either the computer or by teacher' s instructions.

The pupils then work through the software package at their own pace. This model is particularly applicable to the problems associated with providing pupils with extension or remedial material or even to catch up on some missed lessons. Teachers of course need to have access to a large amount of software appropriate for pupils and of course that it matches the content of the curriculum.

Group work model

This is when there are enough machines, three to five computers where pupils do group work using the computer and if there are pupils who do not have access to a computer, they are doing similar work in groups without the use of a computer. In this 'pupils-centred' learning environment pupils are given a problem, a task or a set of activities to attend. Pupils interacting with the computer do not necessarily work on the same software to give the chance to the other pupils to come and see their work to exchange ideas and thoughts.

Computer labs

Computer laboratories with rows of computer stations or set around the edge of the classroom have their advantages and disadvantages depending again on the needs of the school unit.

The laboratory facilitates activities such as word processing and tutorial applications. The resources can be organised and managed by a single person who is able to provide assistance to teachers using the lab. The most important is that the school needs in

hardware are covered with five or six computer stations, while in another case a much greater number would be needed to be bought to have three machines in every classroom. The laboratory separates the computers from the normal teaching programme of the teacher, with a consequent effect on the whole philosophy of integrating computers into the classroom. For example computers can be easily seen as the focus of lessons and not the material or content being developed. The laboratory can become the domain of computer expert teachers and inexperienced teachers are not encouraged to use the machines.

An important component in the whole procedure of integrating computers into the classroom is the software and the hardware used. Both elements have their strengths and witnesses. The major categories of educational software are: drill and practice, tutorials, educational games, tool-based learning, simulations, problem-solving software, educational adventures (Dublin et al., 1994, p. 67).

The characteristics that make a software program good according to Dublin et al., (1994) and Newhouse and Oliver (1989) include the following:

> It fits easily and directly into curriculum priorities rather than representing some new and different subject matter.
> It has flexibility and versatility. It can get multiple uses at different skill levels.
> It can be used in small groups, as well as for 'whole class lessons
> It motivates pupils, encourages active learning, and promotes higher thinking skills
> Easy to get started on
> It adjusts to different pupils at different levels of ability

It fits the kinds of instructional strategies the teacher prefers; strategies that support inquiry, co-operative learning, problem solving, etc.

Interactiveness, it provides feedback to the pupils to incorrect answers, offers pupils variables they can control.

There are many sources of computer solvable problems in schools particularly concerning pupils learning and teacher preparation. The use of computers in the classroom should allow new learning experiences to be offered (Newhouse & Oliver, 1989, p. 9).

The use of the computer as an instructional aid can provide a number of advantages to the pupils. Information Technology is able to accept responses from the pupil and give an immediate feedback. It is able to determine the amounts of knowledge gained by a pupil and provides information on pupil's progress.

IT provides a variety of presentation and interaction modes that stimulate and maintain pupils' interest and motivation. It provides also the opportunity to increase knowledge and to develop higher order learning skills in an interaction fashion.

The need for computers should cry out from what happens in classrooms and schools. Therefore, problems and questions associated with hardware, software, courseware, and teacher training need to be addressed in the context of the problems or tasks found in schools for which a computer solution is appropriate. We need to consider the following characteristics:

1. Users, e.g. the teachers and the pupils: the computer literacy of teacher and pupils, developmental age of pupils, physical capabilities or disabilities of pupils.

2. The layout of the classroom.

3. Educational application.

There is some recent evidence that schools use computers primarily as individualised drill and practice machines and not as tools to support basic learning. Also, pupils from poorer communities and underachieving pupils often get less access to computers. And when they do get access, they are too often confined to drill and practice and tutorial activities (Becker cited in Dublin et al., 1994, pp. 28-29) However evaluation studies draw definitive conclusions about the ultimate potential of computers as a tool used wisely within the regular classroom. (Dublin et al., 1994, p. 28).

G. The introduction of computers in the Primary Education in Cyprus

The subject of Information Technology is itself a young subject in Cyprus schools. The first thoughts began in 1987. The Ministry of Education and the Pedagogical Institute that is responsible for the in-service education of teachers exchanged views and ideas for incorporating computers in primary education. One of the first and main concerns was the training of the teachers who would take part in the plan. The Department of Primary Education, "after reviewing the development of information technology world-wide and the experiences gained by other countries, decided to develop a macro plan for the introduction of IT in the primary education" (Combos, 1994, p. 3).

Computers were implemented in Cyprus Primary Education (ages 6 to 11 years old) in 1993. Initially the computers used were Personal Computers 486 SX/33 MHz bought by the Government of Cyprus. Every school was equipped with two PCs and a printer.

The Introduction of Computers in Primary Education Plan was divided into five phases for the years 1993 to 1998. During the school year 1992/93 (May 93) computers were introduced in a small number of schools in Nicosia, the capital of Cyprus, close to the Ministry of Education were educational policies and decisions are taken. By the end of the next year, 1993/94 there were eight schools all over the country working with computers. The Government with two computers and one printer equipped these eight schools. By the end of 1995 there were twenty-seven experimental schools (7.4 per cent of the schools) with an average of 7.2 computers in each school. In 1998/99 another five schools were added to the program. The selection of the new schools was made to add schools from rural areas of Lemesos (one school) and Larnaca (two schools). The schools added in Nicosia (one school) and Pafos (one school) were from urban areas. The schools were selected from the District Co-ordinators and approved by the Ministry of Education and Culture. Buildings, economical status of the parents' association, the willingness of the teachers, the pre existence of computers at the school, were some of the factors taken into account when choosing the new schools.

The new Curriculum does not include any Information Technology Subject. The Department of Primary Education created a trial Information Technology Curriculum which in time it will be published as an add-in for the Curriculum. The official policy regarding the use of computers in schools is to enhance instruction and not a subject for learning. Computers are not treated as a separate curriculum but as "a dynamic mean of teaching that helps pupils to develop basic skills of gathering, presenting and using information" (Combos, 1994, p. 4). There is a cross-curricular use of IT based mainly on the teaching of basic skills in generic software.

Introducing computers to the classroom is a fundamental change in the teaching and learning processes. Computers are used as teaching and learning tools and that "changed the perception of the computer from a novelty to an integrated instructional device" (Erickson & Vonk 1994, p. 1)

In every school there is an IT co-ordinator. Teaching with the computers is more demanding than traditional teaching. The introduction of computers in each school unit was left in the hands of the school co-ordinator, like the placement of the machines into the classroom, the allocation of time for learning some Information Technology skills and when and how to use computer software programs. The local co-ordinator is working closely with the District Co-ordinator. They prepare teaching materials and work together as multipliers to introduce other teachers to use computers in their teaching.

Although the teaching of Information Technology skills is not fundamental for the pupils, teachers on the other hand need to acquire computing knowledge. In service teachers working with software program is not enough. A Teacher has to know how to use a spreadsheet before trying to teach pupils to use a spreadsheet.

The teaching of some basic Information Technology skills and the use of Information Technology in Primary Education aims to help pupils in the following:

1. To develop their self -image and a positive attitude towards IT.
2. To understand the influence of IT in our everyday life.
3. Using information sources and IT tools to solve problems.

4. To support learning in a variety of contexts.

5. Understanding the implications of IT for working life and society.

Some further instructions and objectives regarding these first steps in using computers in primary schools are can be found in the "New National Curriculum Order for Information Technology" (1996):

Pupils should be taught,

1.To use IT equipment and software to communicate and handle information, and to support their problem solving, recording and expressive work.

2. Use IT to explore and solve problems in the context of work across a variety of subjects.

3. To use IT tools and information sources that help them in their work; understand the limitations of such tools and of the results they produce; and use the concepts associated with IT systems and software and the associated technical terms.

4. To investigate problems by modelling, measuring and controlling and by constructing IT procedures.

5. To discuss some of the social, economical, ethical and moral issues raised by IT.

Combos summarised the experience gained after using Information Technology for one year in a speech at the Philoxenia Hotel, in June 1994:

- There is a need for allocating some time into the curriculum for the development of Information Technology skills.
- Pupils are learning very easily to use the computer.
- Pupils' interest is maintained and there is an increase of their self - image.
- There is a co-operative learning setting.
- Pupils with learning difficulties are helped a lot from the use of computer software.

- The activities of the software programs are close to the interests of the pupils and their learning levels.
- Three computers in a classroom is the ideal situation for pupils to get the most from the use of the computers.
- Computers enable individual pupils to progress and demonstrate achievement.
- Teachers can observe and record pupils' needs and are able to provide individual assistant.

H. Spreadsheets

Spreadsheet is an application software program. Applications programs comprise packages that allow the user to perform tasks without doing the actual programming. By learning how to use a specific application program, the user benefits from the capabilities of microcomputers without devoting hours for doing programming lessons. Other applications software include a word processor (a writing tool), a database (an information handling tool), a graphic package (a painting and drawing tool) and communications program (to enable computers to share information through modems over distances).

The spreadsheet's ability to allow for data correction, addition, or deletion and the automatic recalculation of all formulas and functions after data changes have made make this use of computer spreadsheets invaluable in a wide variety of diverse applications. A spreadsheet is simply an arrangement of rows and columns that set up a grid of cells, into which can be placed values (currency, percentages, etc.), labels (letters, digits, punctuation marks, etc.), or formulas. Data may be then stored and manipulated.

Spreadsheets are large electronic papers where data are stored in rows and columns. A program' s real strength is the power to use commands and formulas to manipulate these large amounts of numbers or values contained in other cells. Changing a number in one of those cells causes automatically the formula to recalculate cell entries controlled by formulae. Furthermore, using the data stored in the rows and columns of the spreadsheet the user can produce graphs and charts very easily.

In education, there are two kinds of uses for spreadsheets; for administrative purposes and learning purposes. "Teachers may use spreadsheets to calculate pupil grades, determine eligibility lists, maintain inventories, and a host of other activities. Pupils may use the software to solve a variety of mathematical problems, maintain club record information and analyse data" (Erickson, 1994, p. 109). For example, a record with pupils' information, teachers' records, pupils' attendance, pupils' activity funds and many more. The advantage in using the program for record keeping is the ease of changing data, adding data or deleting data. Besides storing various amounts of information, simple calculations can be performed on the data.

A pupil's grade book can include for example two types of calculations: the sum of each pupil's marks for tests and average of scores on each test. Many more calculations based upon the data in the spreadsheet can be included, like total class averages.

There are many viable classroom applications of spreadsheets. They can be an "effective tool in the mathematics classroom. There the spreadsheet can be used to solve many real-world problems and, at the same time promote pupils' understanding of important mathematical concepts and principles" (McDonald, 1988, p. 615). In the following

illustration there is a problem from Lockard (1994, p. 96) that can be solved using a spreadsheet:

trial & error

Each cell contains one of the digits from 1 to 9, without repetition.

3	5	7	15
4	9	2	15
8	1	6	15
15	15	15	

Place the digits so that all row sums and column sums equal 15.

III. Research Agenda

Having the skills to solve problems is not only a purpose for learning mathematics but also a major means of doing so. As pupils use problem solving strategies in their investigations of mathematical content, they develop new mathematical understandings and strengthen their abilities to use the mathematics that they know. Problem solving means engaging in "a situation that involves a goal to be achieved, has obstacles to reaching that goal, and requires deliberation, since no known algorithm is available to solve it" (House and Wallace, 1983, p. 10). In order to find a solution, pupils must use their knowledge in different ways and, through this process, can develop new knowledge. Problem solving is an integral part of all mathematics learning and not an isolated part of the mathematics program. It should be "the central focus of the mathematics curriculum. As such, it is a primary goal for all mathematics instruction..." (N.C.T.M, 1989, p. 23).

How can problem solving on a spreadsheet help students learn mathematics? The ability of a spreadsheet to execute mathematical algorithms permits pupils to quickly test and see the effects of varying parameters. It encourages guess-and-check experimentation both in arriving at solutions and in examining the effects when parameters change. Thus, it does not allow the formulation of common errors found while pupils are working on a problem. Further, spreadsheets can be used to introduce pupils easily to problem solving activities with positive results. Together with appropriately designed processes problem can provide a context within which pupils can extend what they know and stimulate deep mathematical investigations.

The teacher plays an important role in the development of problem solving skills by creating an environment in which pupils are encouraged to explore, take risks, share failures and successes, and questions one another in a co-operative setting environment.

Based on the four steps of George Pólya' s (1957), there have been many variations of the problem solving process. Some of the proposed strategies include, act out or use objects, make a picture or diagram, use or make a table, make an organised list, guess and check, use or look for a pattern, work backwards, use logical reasoning, make it simpler and brainstorm.

Pupils will be using a spreadsheet to solve a number of process problems. A variety of approaches can be used to integrate spreadsheets in the classroom, and these approaches differ depending on the teacher's goals for the lesson, the pupils' knowledge of spreadsheets, and the level of pupils' involvement desired (McDonald, 1988, p. 615).

Should these strategies be taught explicitly as they will be working on the computer? Pupils while working on the spreadsheet to solve the problem will be using problem solving strategies and only then will become aware of these strategies, as they arise in the classroom activities. It is only then that the teacher should encourage pupils to take note of them and they will receive instructional attention if we want pupils to learn them. "Learning occurs not as pupils take in mathematical knowledge in ready-made pieces but as they build up mathematical meaning on the basis of their experiences in the classroom" (Yackel et al., 1990, p. 34).

There is research (Schoenfeld, 1987) indicating that pupils' problem solving failures are often not from a lack of mathematical knowledge, but from ineffective use of what they do know. Good problem solvers make sure they understand the problem. If a problem is written down, they read it carefully, if it is told to them orally, they ask questions until they understand the problem. They plan frequently and check what they are. If they feel they are not making progress, they stop to consider alternatives and do not hesitate to completely change what they are doing.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGICAL APPROACHES

I. Introduction – Justification of Methods Chosen

After reviewing the literature about problem solving and its central place in pupils' learning as a fundamental element in the mathematics curriculum and the importance of using information technology as a tool I move now to the research methods chosen to identify if we can use a spreadsheet for the development of problem solving skills and to the methodological issues raised from this study.

There are three established research strategies; experiment, survey and case study (Robson, 1993; Cohen & Manion, 1994). Each one represents a different mode of enquiry suitable for particular purposes, with its unique characteristics:

Experiment: measuring the "effects of manipulating one variable to another variable" (Robson, 1993, p. 40). Experiments can study "any kind of behaviour but are limited by both practical and ethical considerations to 'low impact' variables and research questions" (Robson, 1993, p. 167). Robson (1993) summarises that experiments need to satisfy "strict design requirements" (p. 168). The enquirer needs to know what he is or she is looking for with high specificity because of the "very small number of variables". There is no realism or generalisability.

Survey: "collection of information in standardised form from groups of people" (Robson, 1993, p. 40). Surveys are "limited to topics on which participants are both willing and

able to report verbally. They can give you access to large contemporary populations through representative sampling, and your focus can be on past events" (Robson, 1993, p. 167). Surveys can generalise safely because they rely "on highly structured verbal reports with categories imposed on respondents" (Robson, 1993, p. 168).

Case study: "development of detailed, intensive knowledge about a single 'case', or of a small number of related 'cases' " (Robson, 1993, p. 40). Also, case studies give you "the entrée to variables and research questions concerning individual, naturally occurring entities... They would normally focus on current events and concerns, and while they can provide theoretical generalisations, they do not permit statistical generalisations" (Robson, 1993, p. 167). They involve observation, interviewing and analysis of documents and records. Case studies, because of their intensive nature, focus on a small number of cases. This leads to questions about the representativeness of the findings. The involvement of the researcher raises questions about possible influence on events and persons involved (Robson, 1993). "Case study encourages the use of multiple methods of investigation. It also licences the enquirer to adopt the more flexible and overtly involved stance" (Robson, 1993, p. 53)

Enquiries can be also classified in terms of their purpose. They can be distinguished between "exploratory, descriptive and explanatory" (Robson, 1993, p. 167). Experiments are more suitable for explanatory studies; surveys for descriptive studies and case studies are more appropriate for exploratory studies.

As stated in Chapter One, the purpose of this research project is to examine the use of spreadsheets for the development of problem solving skills in a group of primary school

pupils. The research examines the use of computers as a means of cross-curricular teaching rather than as a curriculum subject, a statement that harmonises with the philosophy of the curriculum planners and designers of the Ministry of Education and Culture, using problem solving as a method of study, that lies at the heart of the mathematics curriculum.

Case Study

From the study of the three different research methods, I have decided to conduct a case study for my research. Case study describes better the methodological approach to follow to derive the best results from this enquiry for the following reasons as explained in the next paragraphs.

Robson (1993, p. 52) gives the following definition for case studies, "case study is a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence".

Case study is used widely in social sciences and educational research using a range of methods of data collection as mentioned above. "The case study researcher typically observes the characteristics of an individual unit - a child, a clique, a class, a school or a community" (Cohen and Manion, 1994, p. 106). The 'case' in this research, is a group of twelve primary school pupils, who are working in a Computer Lab for a period of time, using a software programme to develop certain problem solving skills in their mathematics curriculum and thus using the computer as a tool. The researcher will be the observer of the group and will be responsible for recording pupils' work.

"Traditionally, case study has been viewed as a 'soft' research". It is true that one of the great strengths of case study is its flexibility while experimental and survey work need "considerable and detailed pre-planning" (Robson, 1993, p. 148) before starting the research. Case study "is defined solely in terms of its concentration on the specific case, in its context. In principle it can be as pre-structured or 'emergent' as you wish - or, more accurately, as is appropriate for the purposes of your case study" (Robson, 1993, p. 149). Case study design is a "process during the study" (Robson, 1993, p. 150), doing this with experiments and surveys can be disaster.

In designing a case study, Robson (1993, p. 150) suggests four steps to follow that because of the flexibility of the method, there is need to consider at the start of the study: "a conceptual framework, a set of research questions, a sampling strategy, to decide on methods and instruments for data collection". Case studies are flexible. This initial framework can and should be reviewed after some time into the study. The research should "remain open to alternative formulation, or possible features or relationships not captured in the initial framework. Important happenings or changes late in the study that requires further review of the framework".

A. <u>Developing a conceptual framework</u>

Developing a conceptual framework forces the researcher to be 'explicit', about what he or she is thinking and doing, to be 'selective', that is to decide which are the important features, relationships of importance or meaning, and therefore able to be selective also about which data to collect and analyse. *Pupils will work for a period of two months on a number of problems using a spreadsheet. The design of the problems will aim to develop*

the following problem solving skills: Use or make a table, make an organised list, guess and check, use or look for a pattern and work backwards.

Although I wasn't planning to ask pupils to solve the problems by writing down formulas and rather use pre-programmed worksheets, from the first lessons I noticed that pupils had the ability to write simple formulas. Later during the program, almost all pupils could do some programming by writing simple formulas. This is an additional advantage of conducting a case study, to be able to make modifications during the research. Of course if pupils, from the beginning of using spreadsheets for solving problems are asked to write down complicated formulas, then the research will not examine problem-solving skills but spreadsheet skills. The spreadsheet is the media for acquiring these skills and this is what the research will examine.

Spreadsheet skills were developed simultaneously by solving the problems in the worksheets. The observer will record pupils' work and progress. The project is limited on time and this should be taken into consideration consideration. At the end of the project, some pupils can be interviewed on how they felt using a computer on their mathematics lessons for solving problems.

B. Developing a set of research questions for the case study

We need to have consistency between the questions and the conceptual structure. It is important to ensure that all parts of the conceptual structure diagram are covered by the set of questions, as stated in page 8.

These questions might be re-examined and refined during a review process in conjunction with the conceptual framework, in case they do not seem to be capturing important aspects of what is going on.

C. Developing a set of sampling strategy

A major distinction between experiments and surveys on one hand and case studies on the other is case studies' "lack of reliance on sampling methodology" (Robson, 1993, p. 155). Since it is not feasible to gather detailed information about all the persons involved for all the time they are involved there has to be some kind of selection or sampling following the four w' s proposed by Robson (1993, p. 155):

who Which persons are observed, interviewed, etc.?

where In (or about) which settings are data collected?

when At what times?

what Which events, activities or processes are to observed, etc.?

The answer for each question is determined by the research questions and the conceptual framework that governs the study. First, regarding whom, in this study, things are more obvious and logical in deciding the sample. The whole work is held in the researcher's classroom that takes part in the Ministry's of Education and Culture (Primary Education) project called "Implementing Computers in Primary Schools as a Tool for Learning and Teaching". As far as where and when, pupils will work with the spreadsheet during their mathematics lessons, without changing the program of the classroom. They will not change classroom or even seats, since the computers are situated next to them. This is important because pupils will not feel that they are doing something different from their usual school program, with possible effects on the value of their work, during the project.

A few hours will be used for the development of spreadsheet skills, during the Designing and Technology lesson, just to get the pupils familiar with the software, since this is their second year working in the classroom with computers using MS- Windows ™.

D. Selection of data collection techniques

Case study permits the approach to data collection in a variety of ways and should depend on the kind of study that you are doing. "The conceptual framework, research questions and sampling criteria determine the approach to data collection" (Robson, 1993, p. 157).

Exploratory case study with little on which to base your conceptual framework, very general questions and a weakly defined emergent sampling strategy it is inappropriate to have standardised data collection devices.

Confirmatory study when previous work gives you confidence to a well defined conceptual structure, and a specific well focused research questions with a tight and known sampling strategy, then you can use similarly focused, pre-structured data collection techniques.

A range of techniques is used in a case study; observation, interview and use of documents and records (Cohen & Manion, 1994; Robson, 1993):

Observation (advantages & disadvantages)

Unlike the experimenter "who manipulates variables to determine their causal significance or the surveyor who asks standardised questions of large, representative samples of individuals, the case study researcher typically observes the characteristics of an individual unit" (Cohen and Manion, 1994, p. 106). "Whatever the problem or the

approach, at the heart of every case study lies a method of observation"(Cohen and Manion, 1994, p. 107).

There are two types of observation, participant observation and non-participant observation (Cohen & Manion, 1994; Robson, 1993). In participant observation, the investigator is engaged in the events as if he or she is a member of the group. Non-participant observers, on the other hand, take no part in the group activities they are investigating and avoid group membership (Cohen and Manion, 1994).

Bailey (cited in Cohen & Manion, 1994, p. 106) lists some inherent advantages in the participant observation approach:

a. Observation studies are superior to experiments and surveys when data are being collected on non-verbal behaviour.
b. Investigators are able to discern ongoing behaviour as it occurs and are able to make appropriate notes about its salient features.
c. Case study observations take place over an extended period of time, researchers can develop more intimate and informal relationships with those they are observing, generally in a more natural environment.
d. Case studies' observations are less reactive than other types of data-gathering methods.

Cohen and Manion (1994) point out some criticism of participant observation studies that characterise them as "subjective, biased, impressionist, idiosyncratic and lacking in the precise quantifiable measures" (p. 110).

As to this study, my role will be to teach and to record pupils' reactions. That is I am going to be a participant observer. I have decided to follow this for several reasons. First, this role will give me a better inside knowledge of what is going on in the class. Being the

teacher offers you the possibility to grasp all the reactions of your pupils as they occur. Second, the relationship I created with the pupils gave me the information I could get only after interviewing each one for two hours. Of course to maintain the validity of the research I took some measures described later in the validity and reliability section.

Interview (advantages & disadvantages)

Another technique used in enquiries is asking people questions and then getting a record of their responses that is interviewing. Interviews can be used in a combination with other methods, like in a case study an interview, with its "fluid agenda and open-ended questions" (Cohen & Manion, 1994, p. 226) will complement participant observation.

They appear to be a quite straightforward and non-problematic way of finding things out. An interview is a conversation,

> initiated by the interviewer for the specific purpose of obtaining research-relevant information and focused by him on content specified by research objectives of systematic description, prediction or explanation (Cohen & Manion, 1994, p. 229).

The interview is a flexible and adaptable way of finding things out. It offers the possibility of modifying one's line of enquiry, following up interesting responses and investigating underlying motives in a way that postal and other self-administered questionnaires cannot. Even non-verbal cues may give important messages. Interviewers need to be highly skilled to overcome matters like biases. The lack of standardization that it implies inevitably raises concerns about reliability.

The different types and styles of interviews are based on the degree of structure or formality of the interview (Cohen & Manion, 1994):

Fully structured interview, with predetermined set questions asked, and the responses recorded on a standardised schedule.

Semi-structured interview, where the interviewer has worked out a set of questions in advance, but is free to modify their order based upon his or her perception of what seems most appropriate in the context of the conversation.

Unstructured interview, where the interviewer has a general area of interest and concern, but lets the conversation develop within this area.

Some semi-structured interviews are scheduled at the end of the project in a review stage, depending on time left for data collection and analysis.

Use of documents and records

It includes a range of written or recorded materials like "written curricula, course outlines and other course documents, timetables, notices, letters and other communications to parents" (Robson, 1993, p. 275). The analysis of the documents is called 'content analysis' (Robson, 1993). Content analysis is analogous to structured observation. It is used as a supplementary method in a multi-method study.

Techniques very important to this study is a pre-test, a post-test and a post post-test that will measure pupils' problem solving skills.

Context

Samples

The sample of my research is a group of twelve primary school pupils, aged ten (three pupils) to eleven (nine pupils) years old. They were six boys and six girls. From the records kept in the school, pupils' grades were as follows:

Table 1

Pupil	1st Grade *age 6 years old*	2nd Grade *age 7 years old*	3rd Grade *age 8 years old*	4th Grade *age 9 years old*	5th Grade *age 10 years old*	6th Grade *age 11 years old*
S01	A-	B	A	A	A-	
S02	no records	A-	no records	B	B	A
S03	A	A	A-	A	A	A
S04	A	A-	A	A	A	
S05	A	A	A	A	A	A
S06	A	A-	A	A	A	
S07	A	A	A	A-	B	A-
S08	A	A	A	A	A	A
S09	A	A	A-	A-	B	A-
S10	A	A	A	A	A	A
S11	A	A	A	A	A	A
S12	A	A	A	A	A	A

For the purposes of the research pupils are called S followed by a number from 1 to 12 that has no meaning.

II. Instruments, Data Collection and Date Analysis

In this section I am going to show what I did and how I did to collect the data as well as the instruments I used for data analysis and why I have chosen certain types of data analysis.

A. Research instruments

Sammon (1989) in a statement about choosing the right methodological instrument suggests "some of the most fruitful research involves a combination of methodological approaches" (p. 33). The use of more that one method can improve also the validity of the findings. A pre-test, a post-test and a post post-test were used to gather qualitative data emerged from the research while I was taking part as a participant observer to record the quantitative data from the research.

Tests also play an important role in developing instructional programs and they were used in this study to assess pupils' performance before and after pupils' work on the computers to help the research to determine the success of using a spreadsheet to develop problem-solving skills. Tests aid in the planning of curriculum changes and provide norms that assist in evaluation of school systems. The tests were selected in accordance with learning objectives in the mathematics curriculum.

The three tests were divided in Part A and part B (Appendix C). Part A was consisting of 7 exercises about the four arithmetic operations, addition, subtraction, division and multiplication (five exercises from each operation), about place value (fourteen exercises) and fractions and decimals (eight exercises). Part B was consisting of four process problems. Pupils had to solve all exercises and all problems in 60 minutes. Post-test and post post-test were exactly the same because the second was administered to the pupils a year after the post-test. Pre-test as mentioned had the same form as the other two but with different exercises.

To record my observations during the lessons I created a 'Data Collection Sheet', cited in Appendix E. In Appendix F there is a sample Data Collection Sheet that illustrates how I was recording my observations. First I was writing the problem of the day and the date as well as some information about the groups. The rest of the paper was to help me focus on certain aspects like, the work done in each group, the relevance of their work to the research questions, technical problems as well as a list of attachments, that is in some cases when pupils were using a piece of paper to take some notes I was collecting it and it helped later at home to write down my observations of the day. When carrying out a study

producing quantitative data the question is whether there are differences between the scores obtained under two conditions or by two groups.

B. Analysis

Choosing an appropriate statistical test is not easy. The existence of a large number of statistical tests for a given research design forces the researcher to employ some rationale for choosing among them.

The data from the three tests that I have administered to the pupils were analysed using the statistical package SPSS-X and the following tests:

a) t-test for comparing two means of the same pupil.
b) Kolmogorov-Smirnov two-sample test for testing whether there were any differences between the genders.
c) Wilcoxon Matched-Pairs Signed-Ranks test to analyse the pair of scores of each pupil.

Both the hypothesis and the data of my research require not only to measure each variable for each pupil (Descriptive Statistical Analysis) but also to examine groups' and sub-groups' differences and relationships between variables (Inferential Statistics).

As a consequence, the data were coded according to Youngman' s (1978, p.19) suggestion into whole numbers and analyzed using the SPSS-X program. Having in mind the analytical procedures which can be used for the descriptive statistics (Youngman 1978, pp.53-61; Borg and Gall 1983, pp.363-370; and Fraas 1983) I decided to use percentages,

means, standard deviations and medians to illustrate the variables. The Kolmogorov-Smirnov test was used for the Inferential Statistical Analysis. Although statistical tests were used to identify statistical differences, there is a possibility of making either a Type I or a Type II error. To guard against this, I accepted: a) a level of significance of $p < .05$ in order to determine the Type I error; and b) I used the t-test and Kolmogorov-Smirnov two-sample test which are high-power efficient tests to avoid type II error.

III. Methodological issues: Limitations of the Research

In order to persuade the readers of this research that the findings of this case study are worth taking account of and that an honest job was done I have taken some precautions right from the beginning of the study. These measures were taken so as the results were taken unbiased and without trying to deliver the required answer from my pupils and moreover I tried to secure the privacy of the people who took part in the research. In this section I examine methodological issues in the light of my research topics and design, concentrating on its validity, reliability and ethical implications.

A. Validity and Reliability

Although it is easier to work with written tests and draw quantitative data easily, qualitative data as the observations made to pupils while they work are more limited and difficult. In this section I examine my research methods concentrating on their validity and reliability.

Validity and Reliability having to do with being a Participant Observer

The task I had as the investigator to record and explain pupils' actions in the computer lab, acting as a participant observer, has some inherent advantages as stated earlier. The

same advantages raise some criticisms regarding two types of validity in observation-based research, the external validity and the internal validity (Cohen and Manion, 1994). External Validity forces the investigator to examine whether the results of his/her research are applicable to other situations. Internal Validity has to do with the close involvement of the investigator in the group and whether results represent the real product.

Further to these, other concerns have to do with the reliability of the data obtained during an observation. Robson (1993) refers to 'observer consistency' and 'inter-observer agreement' (p. 221). "Observer consistency is the extent to which an observer obtains the same results when measuring the same behaviour on different occasions. Inter-observer agreement is the extent to which two or more observers obtain the same results when measuring the same behaviour" (p. 221).

Also, to avoid observational biases I constructed the Data Collection Sheet, cited in Appendix E to guide me while recording pupils' reactions in the computer lab. It helped me also to write down in a quick and simple way my observations without loosing conduct with the class. Detailed notes from each session were written down the same evening at home based on the information I was gathering with Data Collection Sheet. While recalling the events happened earlier in the computer lab, more insights were come to my mind and I could explain clearly certain reactions and events happened in the class and were not so important on that moment.

Validity and Reliability having to do with the tests

In most experimental research investigators are trying to reach to a progress and usually, positive results come out of a research. The question is whether these results are true and genuine, without any intervention by the researcher. To maintain the validity and the

reliability of the results I gave to the pupils a post post-test, one year exactly after the post-test. Nine out of the twelve pupils were already at the gymnasium. This eliminates a criticism for 'subject bias' (Robson, 1993, p. 67) where pupils make a strong effort at the test to please their teacher knowing the importance of good results. A thread that has to do with the internal validity of my research from the post post-test is the maturation of the pupils.

B. Research ethics

From an early stage of my planning in conducting a research with pupils ethical aspects and dilemmas have been taken into consideration that were raised from the research settings. Being a teacher of the school and the class teacher of three out of the twelve pupils I had to be very careful in every step I was making.

Before starting anything I spoke to the Chief Education Officer (Primary Education) of my District who agreed to my sending a letter explaining what I was going to do, for the record. At the same time, I talked to my Principal at school who also gave his permission and moreover the permission to use the data kept at school. These data in no way reveal the name of the pupil or his/her gender. For example I use S01 i.e. student number one. Although I was planning to put also a B next to boys and a G next to girls by doing so it could reveal the identity of the only girl from the Fifth Grade. Also, from the beginning I tried not to identify the number with the pupil so as to stay unbiased in my comments. The only time I looked the names is when I analysed the results of the boys in contrast to those of the girls.

My next step was to send an official letter to the Ministry of Education and Culture (cited both in Greek and English in Appendix A) explaining briefly what I was going to do,

asking their permission. They did not reply but the Head of the District Education Office said that his oral permission was enough. Secondly I sent a second letter to the pupils' parents (cited both in Greek and English in Appendix A) explaining clearly what I was going to do saying that if they did not want their child to participate there would be no problem. Only one pupil did not join the group because of the time and another pupil asked to be a part of the group and she/he was accepted.

In all cases the anonymity of the tests has been kept very strictly and so was the gender of the pupil as I was discussing the results. In addition, even the name of the school where I conducted the research is not revealed anywhere in my discussions. In Appendix C where the tests are cited the school logo was removed from the re-prints.

Another big dilemma is my involvement in the research, as the researcher, the participant observer and the coder. Being my self a District Information Technology Coordinator, the person who is responsible for the implementation and the spreading of the use of computers in primary education, is quite controversial with the term un-biased researcher. It is true that I made big efforts in the writing of my work not to see computers as eulogy for education. But, during the lessons I was very strict with my pupils and their work on the computer. In no way did I force them to reach to a conclusion or controlled a situation.

Another point I wish to mention is that the main reason I chose to conduct a case study and not an experimental design with an experimental treatment group and a comparison group was the big dilemma that could lead to unethical treatment of the pupils, who would be in the experimental group and who would be at the comparison group?

As a synopsis to the above, although some limitations of my research can be identified, I tried to contribute to the educational theory and to provide useful data to the decision makers for the implementation of computers in primary education in Cyprus.

CHAPTER 4: RESEARCH FINDINGS

As discussed earlier in the Methodology Chapter, the project took place in a Primary School in Cyprus, between March and June 97. During this phase I worked with a group of pupils aged eleven to twelve years old on a number of mathematical problems, cited in Appendix B. Pupils were using a spreadsheet to solve the problems in order to develop problem-solving skills.

The pupils were already familiar with Microsoft Windows95® and Microsoft Word® when we started the program. First, I gave them the pre-test (cited in Appendix C). Then, we had two general lessons about spreadsheets and their possibilities, strengths and weaknesses. A series of seven ninety minutes lessons working each time on one or two problems using a spreadsheet followed. At the end of this first session, pupils were asked to solve the post-test (see Appendix C). A year later (April 98) the twelve pupils had a post post-test.

During the project I took part in the case study as a participant observer, which meant that in addition to recording pupil's behaviours and attitudes, I was also doing the teaching and the introduction of the problems.

The data collected in the research fall into two categories- words and numbers. Qualitative data for words and other data that come in a non-numerical form and quantitative data for numbers and other data that can be transformed into data.

This chapter is divided into the following parts: first the presentation of the qualitative data (observations) and second is the presentation of quantitative data (tests). Qualitative data emerge from the observations I have recorded during the series of the lessons. The quantitative data derived from administering the three tests, the pre-test, the post-test and the post post-test to the pupils who took part in the programme. Before the presentation of the data, there is a section with a brief description of the lessons.

I. Description of the Lessons

In order to set the analysis of the qualitative and the quantitative data in context I present in this section a description of three lessons, the two introductory and then the first lesson proper.

Before starting the lessons I prepared a 'Data Collection Sheet' (cited in Appendix E) to use during the recording of the observations. Being the teacher and the observer at the same time, the 'Data Collection Sheet' helped me focusing my observations on specific subjects related to the research questions and technical problems. I present in more detail the first two lessons, which were used to introduce pupils to the spreadsheet program Microsoft® Excel 5.0 and the first lesson. Then, there are general comments on the rest of the lessons.

A. Introductory Lessons

The first two lessons were used to introduce pupils to the spreadsheet program Microsoft® Excel 5.0. Pupils were familiar with the basic layout of the program because they all knew Microsoft Word. The basic ideas presented to the lesson were:

- A spreadsheet is like a sheet of paper divided into rows and columns, and into each cell of this grid you can enter numbers, text and formulas.

- Data can be changed easily and after without the normal rubbings and crossings out. It remembers the formulas and recalculates everything when you change the figures.

Skills, concepts and strategies of using a spreadsheet are familiar to the pupils from their science and mathematics lessons. Any pupil can draw a table, add labels to the columns and rows and create a simple or more complex algorithm. The more difficult parts in the introduction of the spreadsheet were the formulas. A simple way was to ask pupils to sum or subtract two numbers in a row or a column by writing a simple formula like: =A2+A3

They were then introduced to the three different ways to write a formula. They practised using different cells and different ways to write the formula. They were asked to subtract two numbers, multiply two numbers and divide two numbers using the same way. They also practised in changing a number to see how the result was changed.

The next step was to teach pupils how to work with useful tools of the program like formatting the cells: adding colour, adding borders around the cells. In the beginning of the second lesson, there was a revision of the material taught in the previous lesson and then pupils were given the following problem:

> By using the digits 1 to 9 without repetition create a square 3X3 so that all row sums and column sums equal 15.

They had to present the solution using the spreadsheet. There was class discussion on how to solve the problem and the formulas we should use. With little help from the teacher, three out of five groups found a solution.

1	**5**	**9**	***15***
6	**7**	**2**	***15***
8	**3**	**4**	***15***
15	***15***	***15***	

Figure 1: The work of Group 1.

By changing the numbers in the cells, they could see the result also changing. During this activity they were introduced to how to copy a formula using the mouse (by dragging the cross of the cell to the left or down).

A subject that I was unsure about before proceeding to this lesson was whether I should give them the table ready with the formulas or not. Finally, I asked them to write the formulas on their own. This is something I discuss later in Chapter 5.

B. <u>First Lesson</u>

A problem from the pre-test was chosen to start the series of the lessons:

> A person paid £1,55 giving 19 coins of 5's, 10's and 20's. How many coins from each did he/she give?

The procedure used to solve the problem was based on the 'four step' method of Pólya (1957) described above (see Chapter 2, p. 14).

The problem was written first on the board and there was class discussion to see clearly what was required. I asked them to retell the story in their own words for a better

understanding of the problem. During this phase I was asking them questions to see whether they understood the problem like: What is the unknown? What are the data? What is the condition?

During the discussion two pupils were trying to guess the solution and did not participate in the class discussion. From the discussion we decided to draw a table where we would mark down the various guesses while doing the operations orally. Pupils suggested their strategies and then they were asked to work on their computer using the spreadsheet to solve the problem. Groups worked alone for about seven minutes without any positive results. All the pupils then sat around a computer to solve the problem. Pupils said that for this first time they would like to work with the teacher to gain confidence to work along with their group without the teacher's help and guidance. Pupils from the Group 1 drew the table on the spreadsheet and added the labels on the columns. By class discussion we added the formulas, checked them and then each pupil gave his/ her guess trying to keep the number of the coins to nineteen. In this phase later, we related the problem to a problem they had solved before. Have you seen it before? Do you know a related problem?

Before proceeding to the next step, pupils clearly understood the two conditions of the problem; first, that the sum of the coins should be £1,55, and second that the number of the coins should be 19. Pupils began to see how the table should be, the order of the columns and the formulas they would need. By watching the table filling with numbers pupils were making observations on what numbers we should try and which to reject. Observations were made on the last digit (5) and on the limitation we had on how many coins of 20 we should use.

The fourth step of Pólya 'Looking Back' is the easiest, since the program provides an immediate answer whether or not they had the solution. In addition, this phase provided the information needed when they followed a wrong strategy or they had a false formula. This forced them to think again the whole procedure, go back to check if they really understood the problem, and recheck their plan.

II. Findings from the Observations (Qualitative Data)

The main observations I made during the case study are presented through a focus on the three research questions, cited in page 8.

During these observations, a number of issues emerged though it needs to be remembered that I was trying to record everything that was happening into the classroom, at the same time as teaching the class. The following categorisation will help to present this information from the lessons more systematically and explicitly. First, I examine how did problem solving using spreadsheets affect pupils' learning. Some of the issues covered are motivation, behaviour, feedback and time on task. Second, how did this method of teaching problem solving skills affect the teacher's work? The focus on this part is on classroom processes – the teacher and the pupil interaction and activity.

Do spreadsheets as a Computer Assisted Instruction application improve learning and teaching in problem solving activities?

In terms of pupils' learning findings from the case study observations suggest some important considerations for pupils' use of computers that include the following:

Motivation

Computers were found to be good motivators. Pupils were very enthusiastic and very anxious to start the project. Although they were trying at first to negotiate some time for "working on other software installed on the computers " when the project started they did not want to spend any time on other tasks. Despite the fact that the project was taking place in the computer lab of the school between 13.30 to 15.00, when all the other pupils finished lessons, pupils' enthusiasm remained high. The group was volunteers and only one pupil did not show interest in participating the project, while pupil S07 asked to join the group. Pupils were not paying any money for the lessons or their return back home. When we had to postpone a session (end of May) because of an obligation I had, a girl was complaining all the morning because she was going to miss her computer lesson and that we should make up this missed lesson later!

Pupils considered these lessons of great importance. Their extra lessons were coming to the end and now they had the chance to work on the computers for some extra time for free. Also, they would have the chance to use a program that only the teacher was using up to that time and that especially made them feel they would be moved to higher levels of learning. The four pupils of the 5th level were more reserved wondering if they could make it although they had the same computer lessons as the other pupils.

During the first two lessons, all groups except Group 1 were asking teachers' help feeling uncertain about how to start. Group 1 (S10, S11, and S08) was asking help on how to format the tables. This group was also the first to finish during these two lessons. The nature of the work was such that pupils received immediately feedback, either the problem was solved or not, and that increased their motivation. Especially Group 5 (S01,

S03 & S05) was the group that made a great effort and these pupils were the first to finish in most of the problems.

Time on task

The time pupils spent on each problem varied from group to group. The majority of pupils showed high levels of concentration while using computers for solving problems. This concentration was often sustained over fifty to sixty minutes or more. Usually, after five to ten minutes of class talk about the problem, which was written on the board, pupils needed about thirty to forty minutes to solve the problem, including the formatting of the tables.

In one case, pupil S11 was trying to solve the problem using pencil and paper. I asked him/her to try to show his/her abilities by providing also a solution using the spreadsheet. A pupil of high ability can be easily get tired trying to do something he/she could easily solve even orally, using the spreadsheet or pencil and paper. In this case the teacher should be prepared to offer more complicated tasks to keep the pupil interested and satisfied.

Pupil S08 was a natural leader in Group 1 and the person who was guiding the others. During Lesson 4 the pupil was asked to join Group 3 that was facing some problems. Also the other two pupils of Group 1 had to take responsibility of their work (S10 & S11). Nevertheless S08 did not do well in the post-test although I was expecting a much higher score because of his/her performance in the class. Pupils S08, S09 and S10 were of my morning class, which was an experimental class for the introduction of computers.

We tried to solve problem 6 on the board without the use of computer just to show that computer software are tools and that we can do all the work using pencil and paper, although this might take longer. That action had a great impact on pupils` attitude towards problem solving. We solved it by group work, and that reinforced in the pupils` minds that mathematics is not only formal teaching in the class or using computers but it is the developing of certain skills. They were all very happy to be able to help solve the problem on the board and they all remembered the first time we tried to do the same thing, not long ago which had seemed to them as something of big difficulty. Pupils worked effectively in a collaborative environment, which is discussed in Chapter 5 more thoroughly.

Most pupils were entering the computer lab on time, without any delays, sitting with their group and waiting for the presentation of the new problem. They were working quietly, with their group, trying to finish first.

During the last ten to fifteen minutes, when some groups had finished their task there was some deterioration of behaviour. Pupils were tired because of extending mornings' lessons. There was no abuse of the systems or vandalism. Pupils were learning things on their own by observing the tables. They learned how to write down all the numbers but they were also thinking

Pupils enjoyed working in the computer lab, despite doing mathematics. They liked the atmosphere of the place: freshly painted, new big tables, electronic machinery all around (computer hardware), a whiteboard instead of the blackboard. All these had a positive effect on pupils' behaviour and attendance. There were no problems of behaviour at all.

Also, during our meetings only one pupil had to miss a meeting because she had to study for her piano examinations.

As discussed earlier, I was taking part in the project as a participant observer. My observations as the teacher of the classroom, as a researcher and as a member of the school staff are summarised in the following paragraphs.

Although I was the only teacher involved in the program, other staff of the school were aware of what I was doing. During the project I used to exchange ideas with colleagues who used to come into the lab during the lessons and watch the pupils working. This made a teacher use a spreadsheet for introducing the basics of plotting graphs to year four pupils (9 years old). We worked together and prepared a series of lessons. Another teacher, who taught in the higher levels, was very sceptical about using computers for teaching and introducing problem solving skills expressing doubts on the effectiveness of such methods. However, two other teachers incorporated in the mathematics lessons the introduction of the 'four step method' and the teaching of problem-solving strategies more systematically. Unfortunately they did not use a computer for the introduction of these problem-solving strategies for comparing later their experiences and results, with my project.

Some class teachers tended to be unenthusiastic at the beginning of the project by the fact that another teacher was teaching their pupils. The fact that I was teaching actually the same things in a different way made them feel that I was undermining their work. Also, the fact that those pupils were anxious to come to the lessons made them feel some jealousy.

III. Findings from Pre-Test, Post-Test and Post Post-Test (Quantitative Data)

The following paragraphs present the results from the three tests the pupils undertook. The test was divided into two parts, the first part was an attempt to examine pupils' abilities in relation to control variables and in the second part I tried to find out differences in relation to dependent variables (problem solving).

A. Differences on pupils' abilities in relation to control variables

This part of the test consisted of twenty exercises, five from each arithmetic operation. The main purpose for adding this section was to test whether there were any differences in pupils' progress after their work on the spreadsheet.

a) Four arithmetic operations (natural numbers)

Table 1 illustrates percentage of success of each pupil in the tasks concerned the four arithmetic operations and the average percentage of success of the four arithmetic operations. To find out the percentage of success of each pupil I was dividing the number of correct answers with twenty and multiplying it with 5. In some instances there is some progress, as with pupil S10, who has the biggest increase, +25 marks (i.e. from 15 out of 20 to 20 out of 20). Moreover the differences between the scores of each pupil, in the pre-test and in the post-test are presented in Table 1.

Pupils	Total Pre test	Total Post test	Difference
S01	80	80	0
S02	85	80	-5
S03	80	90	10
S04	90	90	0
S05	85	100	15
S06	75	80	5
S07	70	80	10
S08	95	80	-15
S09	75	70	-5
S10	75	100	25
S11	90	95	5
S12	95	100	5
Average	82.92	87.08	
StDev	8.02	9.67	9.97

Table 1: Percentage of success of each pupil in the tasks concerning the four arithmetic operations to the pre-test and the post-test.

The differences between the scores obtained in the pre-test and post-test are between -15 and +25, with -15 and +25 indicating each one only one case.

Other observations drawn from Table 1 are:

Pupils have shown a progress in the post-test with a mean of 87.08 while giving 82.92 mean in the pre-test but with no statistical significance ($t = -1.10$, $df = 23$ and $p > .05$).

Pupils S01 and S04 presented no differences in the two tests, while three pupils have a decrease ranging to –10%.

There are no statistical significant gains by observing separately the results of the four exercises. Table 1 in Appendix D presents the results from Exercise 1 from the four arithmetic operations and reveals that there are no significant differences between pupils' responses to the pre-test and to the post-test.

It is also important to note that the results of Addition Exercises are the same in the two tests. Pupils S04 and S05 who are the only pupils who scored 4 in the pre-test, scored again 4 in the post-test.

b) Place value - Fractions and Decimals (Exercises 2 to 7b)

Further to the above, in this Part of the test there are five exercises, measuring pupils' abilities on Place Value, Fractions and Decimals. These exercises were added to test any differences in pupils' progress after pupils' work on the spreadsheet.

In these exercises similar observations with Exercise 1 can be made. Pupils' general results present no statistically significant differences. Pupil S10 again presented the biggest difference (-37.50) but this was a negative difference indicating that S10 did better in pre-test than in post-test. Nine out of twelve scores vary from –12.50 to +12.50 and that implies that the results to pre-test and post-test were similar.

Table 2: Percentage of success of each pupil in the tasks concerned, Fractions & Decimals (Exercises 2 to 7b)

Pupils	*Percentage of Success*		
	Pre-test	*Post-test*	
S01	**50.00**	**62.50**	**12.50**
S02	**50.00**	**37.50**	**-12.50**
S03	**87.50**	**62.50**	**-25.00**
S04	**75.00**	**87.50**	**12.50**
S05	**75.00**	**62.50**	**-12.50**
S06	**75.00**	**62.50**	**-12.50**
S07	**50.00**	**50.00**	**0.00**
S08	**62.50**	**62.50**	**0.00**
S09	**37.50**	**37.50**	**0.00**
S10	**87.50**	**50.00**	**-37.50**
S11	**87.50**	**75.00**	**-12.50**
S12	**75.00**	**100.00**	**25.00**
Average	**67.71**	**62.50**	
StDev	**16.50**	**17.68**	

Pupils have a higher average in the pre-test (67.71) from the post-test which is however not statistically significant. In addition, the standard deviations are more or less equal and this implies that pupils after the series of lessons there was no change, positive or negative, in pupils' ability regarding solving addition exercises. Thus, by using t-test we did not identify any statistically significant difference between pupils' responses to the pre-test and to the post-test in relation to exercises 2 to 7b concerned with Fraction and Decimals ($t= 0.71$, $df= 23$ and $p< .18$).

Three pupils present no change while three pupils increased their average. Six out of twelve pupils lowered their average in the post-test with pupil S10 having the greatest negative difference (–37.50).

Table 3: Percentage of success of each pupil in the tasks concerned, Place Value. Exercises 2 to 7b

	Total Pre-test	*Total Post-test*	*Differences*
S01	**69.23**	**69.23**	**0.00**
S02	**53.85**	**61.54**	**7.69**
S03	**92.31**	**84.62**	**-7.69**
S04	**76.92**	**84.62**	**7.69**
S05	**92.31**	**100.00**	**7.69**
S06	**84.62**	**92.31**	**7.69**
S07	**53.85**	**53.85**	**0.00**
S08	**100.00**	**92.31**	**-7.69**
S09	**69.23**	**61.54**	**-7.69**
S10	**92.31**	**92.31**	**0.00**
S11	**92.31**	**92.31**	**0.00**
S12	**84.62**	**92.31**	**7.69**
Average	**80.13**	**81.41**	
StDev	**14.88**	**14.88**	

Exercises in Part A are grouped in three categories: Four Arithmetic Operations, Place Value and Fractions and Decimals. Overall results show that pupils present the biggest average in the Four Arithmetic Operations (82.92 to 87.08 - Table 1), second come the results in Place Value (80.13 – 81.41) and finally, with a remarkable difference, are the results in the Fractions and Decimals exercises (67.71 to 62.50 - Table 2). Although pupils seem to decrease their average in the Fractions and Decimals exercises in the post-test ($t= -0.20$, $df= 23$, $p< .24$) this is not a statistically significant difference and cannot be taken into account.

B. <u>Differences in Relation to Dependent Variables (Problem Solving)</u>

Pre-test and post-test consist of four different problems each. Pupils had to solve each problem and give a full answer. The score given to each problem was:

0: if they presented no answer or showed no strategy.

1: If they used an incorrect strategy.

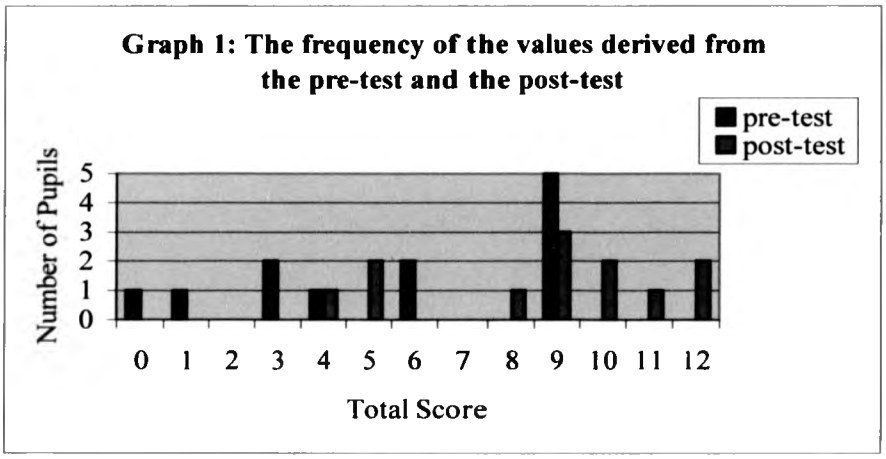
2: If they used no correct strategy but gave no answer.

3: If they used correctly a strategy and gave a correct answer.

The data obtained after marking the problems are ordinal data, since the distance between each value cannot be considered as equal (Youngman, 1979). For this reason, the pair of scores of each pupil is analysed using a non-parametric test, the Wilcoxon Matched-Pairs Signed-Ranks test (Siegel, 1956).

C. Findings from the Pre-test and the Post-test

Graph 1 shows the frequency of the total scores obtained by the twelve pupils in the four problems included in the pre-test and the post-test. The highest value a pupil could get was 12 while the lowest was 0.



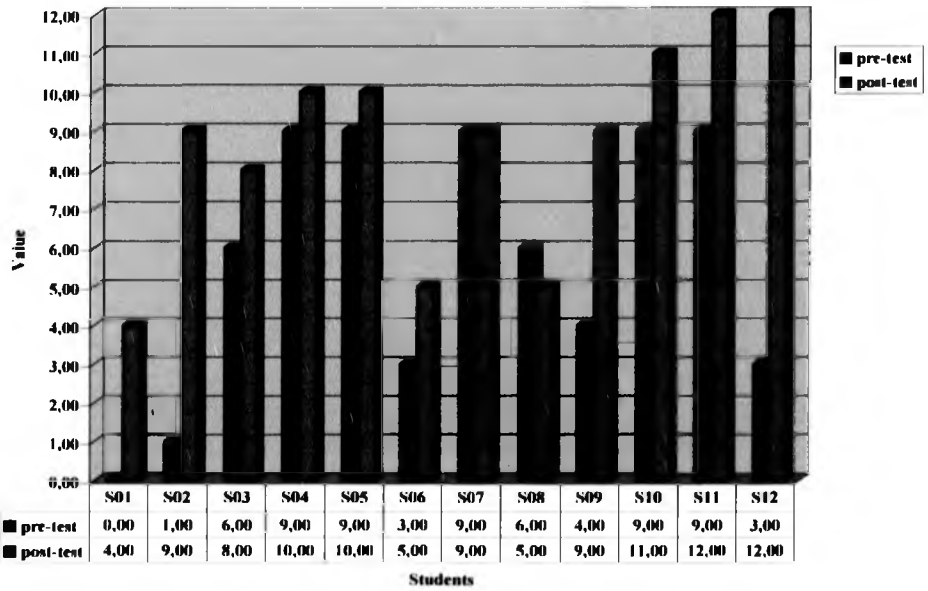
The following observations arise from Graph 1 from the pre-test. Before the implementation of the programme there was a pupil who could not solve any problem and hence his/her value is 0. Moreover, there was no pupil who achieved more than 9, that is no one has solved all the problems correctly. The most frequently occurring value is nine and cumulative percentage indicates that 58.3 per cent of the pupils had a score below six.

In other words, the mode of the distribution was nine and the median was six. Table 3 (located in Appendix D) indicates that Problem 1 in the pre-test (Appendix C) was not solved by any pupil.

The following observations concerning pupils' responses to post-test arise from Graph 1. As with pre-test, nine is the most frequently occurring value. However, the median is nine and from the distribution we can see that 41.7% of pupils' scores was higher than 9 out of 12. Moreover, more than 2 out of 3 pupils' scores in post-test were higher that six. Zero values are missing from the post-test and moreover two pupils (S11 and S12) scored 12; that is, they solved all the problems correctly. Minimum value in the post-test is four.

Graph 2 presents the total scores achieved in the pre-test and the post-test for each pupil. The following observations arise from Graph 2. Ten out of 12 pupils had a positive

Graph 2: Total score achieved in the pre-test and the post-test



	S01	S02	S03	S04	S05	S06	S07	S08	S09	S10	S11	S12
pre-test	0,00	1,00	6,00	9,00	9,00	3,00	9,00	6,00	4,00	9,00	9,00	3,00
post-test	4,00	9,00	8,00	10,00	10,00	5,00	9,00	5,00	9,00	11,00	12,00	12,00

change. Moreover, pupils S02 and S12 have a remarkable increase. Pupil S02 scored 1 in the pre-test and 9 in the post-test while S12 raised his/her performance from 3 marks in the pre-test to 12 marks in the post-test. The use of a spreadsheet to solve problems and the development of problem solving strategies through this process helped ten out of twelve pupils to make a progress, small or big.

Only one pupil, S08 who from the observations during the lessons had a very good performance in the class lowered his/her score in the post-test 1 mark. Pupil S09 did not present any change in both tests but he/she got 9 out of 12 in both tests.

Some further observations derive from **Table 3** in Appendix D are the following. Problems 1 and 4 in the post-test have a very high mean (2.83 and 2.75) showing that almost all the pupils solved them. In addition, seven pupils solved Problem 4 in the pre-test correctly but the rest did not use any strategy or gave no answer. Results from Graph 1 and Graph 2 reinforce the idea presented earlier in Chapter 2 that problem solving is at the top of the most difficult mathematics topics to learn. However, after the attendance of the short course, the study of the graphs, tables and figures confirm that there are positive effects on pupils' learning from the use of a spreadsheet for the development of problem solving skills. The Wilcoxon test revealed a statistically significant difference between pupils' performance before and after the seven Lessons' Course ($D=2$, $N=12$, $p<.006$).

Findings from inferential analysis

In this section, I try to find out whether there was any statistically significant difference between boys and girls. I also present pupils' socio-economical status, having in mind that research on using computers in education reveals that pupils from poorer communities get

less access to computers. And when they do get access, they are too often confined to drill and practice and tutorial activities (Becker cited in Dublin et al., 1994, p. 28). Pupil's performance in all lessons is discussed as well as their results from a post post-test that was administered to the pupils one year after the implementation of the programme.

Gender differences

The average grade of the six girls taking part in the project is 40.28 in the pre-test and 72.22 in the post-test. The total average in the pre-test is 47.22 and in the post-test 76,34. In both cases, girls' average is lower than the total score. Boys' average in pre-test is 54.17 and in the post-test is 76.34, in both cases, higher than the total average. However, girls increased their average almost 69 per cent, while boys increased it only 41 per cent. Nevertheless, the Kolmogorov-Smirnov two-sample test did not reveal any statistically significance difference in performance gains recorded between the genders. Yet, boys were more enthusiastic about working on the problems feeling more confident, while girls were more reserved. One explanation could be that boys are more familiar with electronic devices than girls having in mind all those video games they are playing for hours.

The socio-economic background of the pupils

Records kept in the school official books, like the Register Book do not show differences in the pupils' socio-economic background. They live in the Refugees' Government Housing near the school and they come from different places of the occupied areas in Northern Cyprus. Most of them belong to the working class; mainly they are self-employed, drivers, farmers and labourers. Two parents work in a hotel, one in the civil service and one parent working in a nursery school, the only parent who has graduated from a higher school. There is an economical growth in the community due to hard work.

Pupils' socio-economic background is the same and it was not possible to do any kind of comparisons in terms of their improvement. The above information was taken from the Register Book with the permission of the School Principal. However, a factor that was not analysed is the parents' expectations and whether this factor could influence in any way pupils' results.

Ability

Almost all pupils' ability was very high, according to the records kept in the school. Pupils present the following image as from their last marking: nine out of twelve have an A and three out of twelve have an A-. Thus, ability as a variable cannot be considered in comparing pupils' achievement in the three tests.

Findings from the Post Post-test

The post post-test was given to the twelve pupils one year after the project (April 98). Nine pupils had left primary school while the other three were in the sixth level. The nine pupils were asked to visit school in the afternoon to have a test similar to the one they had one year ago. They were all very happy to return to their old school for a while even if that meant having another test. A comparison of pupils' results to the post-test with their responses to post post-test did not reveal any statistically significant differences. Other factors that might have occurred, like maturation and the study of higher-level mathematics are not examined and hence do not allow us make any additional comments on this.

IV. Further Observations (Lessons 2 to 7)

Below are presented briefly some general observations from the lessons that were factors that were not included in my research questions. These are included because of their

potential for other researchers. These observations were recorded on the 'Data Collection Sheets' (cited in Appendix E) I was using to write down my notes in the classroom. They are elaborated later in the Discussion Chapter.

Learning

- Pupils gradually began to observe the relationships between the data on the tables (variables).
- When pupil S08 changed group because of his/her dominance in the group it helped the others to take control of their learning and not rely on a pupil to do the job.
- Some pupils were trying to solve the problems using pencil and paper. I did not prevent them since the main goal was to develop problem-solving skills.

Technical Problems

- There were some technical problems. For example, for two lessons, a computer was out of order and the group had to split into the other groups.
- There some cases where pupils did not save their work and lost their data.

In this Chapter I have presented the Findings of my research that emerged from my observations during the lessons and from the tests the pupils undertake. The main findings from my study are:

I. Progress in problem solving ability: Pupils have increased their abilities in problem solving after using a spreadsheet to solve a series of problems.

II. Progress in problem solving ability after one year: Pupils did not increase or decrease their ability in problem solving as emerged from the post post-test.

III. There were no problems of communication between the pupils during their work in the groups.

IV. Teacher' s work was more demanding with a major change in his role, from a knowledge dispenser to a facilitator.

CHAPTER 5: DISCUSSION OF THE RESULTS

During the school year 1993-1994 the Department of Primary Education (Ministry of Education and Culture, Republic of Cyprus) decided to implement "Computers in the Primary Education as a tool for teaching to seven schools (2 per cent) around the country. By the school year 1998-1999, the number of schools in the project had increased to 32 (9.41 per cent). Since 1993, a large number of educators conducted a series of studies, designed to measure teachers' and pupils' attitudes towards the innovation (e.g. Kanaris et al. 1995). This is the first research in Cyprus that attempts to measure the impact of a certain kind of software (a spreadsheet) for problem solving, on pupils' learning and teachers' teaching. Policy makers in the Ministry of Education and Culture may come to realise that this kind of research is essential for the evaluation of all software used in the classrooms and to encourage teachers to conduct small surveys like this. Moreover, the Department of Education is more capable of conducting wider experimental research to measure quantitative data from the innovation. Either by using the traditional method of "Pre-test post-test control group design" or in order to measure also the effect of testing to use the "Solomon 4-group design" considering that there are only thirty-two experimental schools around the island.

In the light of my involvement as an Information Technology Coordinator in my school in the years 1994 to 1997 and as a District Information Technology Co-ordinator in 1997-1998 and 1998-1999, I had the opportunity to observe and examine closely the implementation of computers in primary schools. I could observe the eight schools of my District and know from the meetings with the other Co-ordinators and from frequent visits what was happening to the other Districts.

Evaluation of the program has been restricted. The filling of a standard form at the end of the school year by the school co-ordinator is the only official feedback from the experimental schools.

The results presented in the next pages can help in some degree the work of the Ministry of Education and Culture. This research has shown that pupils, after using an open-ended software, developed higher levels of thinking.

The Review of the Literature Chapter covers two topics: Problem Solving and Information Technology. The question of this research is whether problem-solving skills can be developed by the use of IT and more specifically, from spreadsheets. In the pages that follow, I am going to connect the results of this research to these topics and point out the contribution of this study to the development of a new approach to the use of computers in primary education.

This Chapter is divided into the following parts. First is the discussion of the findings: the qualitative data from the observations made of the pupils and the teacher and the quantitative data from the tests. Next follow the limitations of the study with methodological issues regarding the way the research has been conducted. Finally, there are some directions for further work with policy implications and future research for people who might want to investigate more deeply the issues which emerged from this work.

I. Discussion of Findings

A. Discussion of qualitative data: Implications for the process of teaching problem solving skills through the use of IT

A teacher's work can be divided into the following three interrelated tasks: the preparation of the teaching objectives according to the curriculum; the presentation of the new material to the pupils; and to evaluate and get a feedback on the effect of the knowledge, skills and attitudes he/she has helped his/her pupils to acquire.

The use of software like a spreadsheet for teaching any material and especially "problem solving skills" is quite demanding and difficult. It made this three-step work for me even harder since problem solving lies at the heart of the mathematics curriculum. The preparation of the material before each lesson and the work during the lessons was quite demanding for me. I had to modify the teaching materials according to the age, the abilities and the interests of my pupils. I need to repeat here that three out of twelve pupils were 10 years old and the others 11 years old. Adding to this, being my self an experienced person in using computers and able to solve technical problems that arise, a non experienced teacher in using computers and teaching with computers, will be very stressed in a teaching setting like this. We need to consider the support that should be given to these teachers, and whether this support is going to be from the school or outside the school.

At the beginning of this research, I needed to consider the time in which the teacher-researcher and the pupils were to complete these extra-curricular tasks. Although the

pupils who took part in the case study were already familiar with Windows 95 and MS-Word, which has the same layout as MS-Excel, I had to allocate some time teaching them the skills to work with the new software (MS-Excel 5.0). In addition, the whole project took place in a non-teaching time. At first, together with my Principal we decided to work with my morning class (age 11years old). By the end of the first eighty minutes lesson, we realised that I would not be able to work with that group of pupils. The main obstacle was the time I would have to allocate for the various activities of the research. Being at the same time the class teacher, I was responsible for teaching a certain amount of mathematics curriculum in a certain period of time and of course working collaboratively with the teacher of the second class of the Sixth Grade.

If we are going to use spreadsheets as a method of making teachers' jobs easier so that teachers could devote themselves to the "human side" of teaching, it is a naive thought. Teachers are agreed in concluding that in the early stages of any technology implementation their job becomes harder. The technical demands posed by technology use are just the tip of the iceberg. Teachers must be able to select, adapt, or design technology-enhanced materials that meet the needs of their particular pupils. Technology-enhanced curricula often place new demands on teachers' subject matter knowledge and nearly always require them to take on new roles as curriculum designer, team builder, and coach.

Complex, collaborative technology-based work can make assessing individual pupils a complex task. Teachers might well ask themselves whether their involvement with technology will be worth the trouble. The response from my experience as a teacher who has tried it would be positive. Teachers involved in the kinds of activities described in this

study find a new sense of mission and professionalism. They stick with technology, despite the growing pains it causes, because they sense that their pupils are learning more and approaching their classroom activities with a heightened level of motivation. Moreover, the new skills that the teachers themselves acquire, and the satisfaction of facing a challenge and overcoming it, add to teachers' sense of professional growth.

Although technology poses many challenges for teachers, it also provides powerful tools for supporting the teacher's work. New software makes developing and modifying technology-based materials easier (although there is still much room for improvement). Finally, technology is making it possible for teachers to break out of their traditional isolation, communicating with outside content experts and their peers about the instructional content and pedagogical issues that are the heart of their work, and communicating with parents about expectations, activities, assignments, and pupil progress.

Furthermore, when teachers use technology as a critical part of an inquiry-oriented learning-teaching process, they face a set of challenges, including the following: learning how to use a variety of technology applications; using, adapting, and designing technology-enhanced curricula to meet pupils' needs; expanding content knowledge; taking on new roles; and responding to individual pupils.

Implications for pupils

The introduction of new technology into the teaching and learning of problem solving skills initiates a change in power relationships between pupils and teachers. These technologies give pupils more control over their own learning. As a result the teachers'

role is more co-operative, being now a member of the learning group. Problem solving is, as repeated earlier, the most difficult mathematics topic. During the project, a group of twelve pupils, age ten to eleven years old have been using a computer software program to solve 'process problems'. At the same time, without having a direct teaching on problem solving strategies, they were developing the skills necessary to solve the problems.

By using the spreadsheet, pupils were following Pólya 's (1957) 'four step method' for solving a problem. At first, they read the problem to understand the meaning of the problem and the requirements (Understand the problem). Then, they were planning how to draw the spreadsheet, the variables they would use and the formulas they would need. They were then checking how the data were connected and related to the unknown (Devise a plan). Afterwards, pupils worked on the computer to draw the spreadsheet (Carry out the plan). During the filling of the cells of the table, they kept reviewing and examining the solution discussing in their group the problem's parameters, and the range of numbers they should use (Look back).

When working on those problem-solving exercises I noticed errors of thinking, similar to those summarised by Fisher (1990). I tried to eliminate these mistakes of thinking by making use of the possibilities offered by the computer software and the group-work. For instance, there were cases when a pupil was persistent and demanding that the group should follow his/her thought ("egocentric thinking-it's right because I think it is right", p. 12) or when two pupils were going against the other ("trusting others' judgements - it's right because he/she says", p. 12). The ability of the spreadsheet to execute mathematical algorithms permitted pupils to quickly test and see the effects of varying parameters.

Moreover, in the cases where pupils were trying to distract others' judgements, guess-and-check experimentation helped in arriving at solutions and in examining the effects of parameter changes, avoiding thoughts like "it's right because you are wrong!" (p. 12). Thus, it does not allow the formulation of the above errors because pupils can test immediately all the assumptions they made or their group made. Pupils avoided also "errors of perception (it's right because part of it is right), trusting first judgements (it's right because it looks right) and errors of logic (faulty arguments, moving from the part to the whole arguing from the irrelevant)" (p. 12).

Except for the use of the 'four step method' and the possibilities offered to pupils' thinking, the use of a spreadsheet could introduce pupils easily to problem solving activities with positive results. According to Fisher (1990) problem-solving used in mathematical learning can: motivate children and generate enthusiasm; provide opportunities for creativity; build confidence and independence; develop collaborative learning; enable children to apply facts and skills already acquired; encourage discussion and investigative activity; show mathematics to be useful, meaningful and valuable.

B. <u>Discussion of quantitative data: Implications for the pupils' learning (final outcomes)</u>

Differences in pupils' abilities in relation to control variables: four arithmetic operations and place value.

The results derived from pupils' responses to Part A of the tests revealed no statistically significant difference in pupils' performance. That was something expected since the use of a spreadsheet with automatic calculations did not give pupils the chance to practise in any way orally or in writing the four operations. Pupils did not gain anything as far as

their ability in the four arithmetic operations. It is also important to note that they did not have any negative effect on their skills in doing these four operations. Although the work done on the spreadsheet was focussed on writing equations and developing problem solving skills, pupils still had to be able to choose the right operation to complete the formula. The need of pupils to possess certain computational skills presents an important issue. When is the right time to start using a spreadsheet to solve problem solving skills?

Deciding where to begin a discussion of problem solving is difficult in the extreme. After all, in a general sense, skill in problem solving is the ultimate goal of education at all levels. It is even possible to argue that problem solving is the principal activity of human beings and the single ability that most clearly distinguishes their activities from those of other animals (Fisher, 1990).

Adding to the dilemma is the fact that the subject is controversial. There is little agreement about what constitutes problem-solving, whether or how it should be taught, and whether or not problem-solving skills learned in one context can be transferred to problems in another (Maddux et al, 1992).

Problem solving can and should be used to help pupils develop fluency with specific skills. Waiting until pupils "know enough" before giving them problem-solving opportunities deprives them of the experience of grappling with a challenge and leaves them bereft of problem-solving experiences. Nevertheless, it is also true that problem solving does not take place in a vacuum; it requires some content knowledge. For example, consider the problem of the teacher who says, "I have pennies, dimes, and nickels in my pocket. If I take three coins out of my pocket, how much money could I

have taken?" (Adapted from NCTM 1989, p. 24) Knowledge is needed to solve this problem—the knowledge of what pennies, dimes, and nickels are worth and some knowledge of addition. Pupils do not need to be fluent with addition before working on this problem; in fact, working on this problem provides a good context for practising addition skills. The important mathematical goal of this problem—helping pupils to think systematically about possibilities and to organise and record their thinking—need not wait until pupils can add fluently.

As pupils use problem-solving approaches in their investigations of mathematical content, they develop new mathematical understandings. Using a spreadsheet to solve mathematical problems does not exercise the ability of pupils to add, subtract, multiply or divide but it strengthens their ability to use the mathematics they know.

Discussion of findings in respect to dependent variables

Problem Solving

The pre-test scores indicated that pupils did not possess any problem solving strategies before the research or pupils were not used to solving problems in any other way than using an algorithm. Results from the pre-test show 58.3 per cent of the values being below 6, that is, seven pupils solved only one or two problems out of four, or used an incorrect strategy on one problem. The other five pupils solved three problems (value 9). Having in mind that these twelve pupils are of higher abilities, according to the records kept at school (see Chapter 3, p. 60) we would have expected that they would have solved some of the problems. The aim of this case study was to help them develop the skills needed to solve process problems and be able later to transfer this knowledge in other mathematical

context and of course in their everyday life. Pre-test shows evidence of how pupils considered and handled problem solving.

No pupil solved Problem 1 in the pre-test. Pupils did not present any answer or showed any strategy for this problem. Problem 1 might not have been a good choice, as these results indicate and as discussed later in the Limitations of the research. Appropriately designed problem situations provide a context within which pupils can solidify and extend what they know. Although the selection of the problems was made to have a variety of situations and problem types, the teacher must be aware that well-chosen problems can stimulate deep mathematical investigations.

After working with the computer, pupils showed progress in solving problems, with two pupils scoring 12 and 6 pupils between 9 and 11. For the purposes of this study, it is important to note that all pupils used problem-solving strategies to get a solution to the problems and all pupils, according to Graph 1, solved one problem. For example, pupil S01 who scored 0 in the pre-test, at the post-test he/she solved one problem and worked on a second using an incorrect strategy. Pupils that are more able like pupil S11 and S12 solved all four problems with S12 scoring 3 in the pre-test!

Some of the difficulties pupils faced while working on problem-solving exercises were, as Kroll and Miller (cited in Oweans, 1993) say, attributed to the lack or inadequate experience of the following:

- Knowledge factors (algorithmic/linguistic/conceptual and strategic knowledge);
- Beliefs and affective factors (attitudes and beliefs about problem-solving);
- Control factors (awareness of their knowledge and thinking

- Process and ability to monitor this process;
- Socio-cultural factors (the environment the children growth).

In order for the above difficulties to be eliminated or reduced, the following actions and suggestions were considered and taken during the project. Problem solvers must be motivated to solve the problem. The biggest motivator in this program is the computer itself together that the whole program was taking place outside the school time and the formal teaching. They must have an extensive foundation of knowledge and experience. Pupils came to the classroom mathematically literate. This program gave them the experience they needed on problem solving strategies. Further to this, they must possess a feeling of power and repertoire of possible actions. The spreadsheet made it possible to work repeatedly trying to solve a problem in different ways. It gave them the ability they needed to act and to evaluate their actions.

Further, it is important to stress the advantages of problem-solving exercises using a spreadsheet with reference to the aforementioned guidelines. Such exercises can:

- Lead to group work and interaction between individuals;
- Stimulate divergent thinking, creativity and inventiveness;
- Aid the development of concepts;
- Assist the development of α range of process skills;
- Help children to learn to cope with new situations, since they have gained experience in working with others, planning activities and coming to decisions;
- Put children into the situations, which are closer to those in the world at large, than are usually encountered in an educational establishment. (Stoker, 1986)

C. Discussion of findings from the differential analysis

Gender Differences

There are no significance differences recorded between boys and girls, despite that in both pre and post-test boys' average is higher than girls' average.

Before the program, pupils were using an algorithm to solve problems and in no case any kind of strategy, as shown by the pre-test. Post -test has shown that both boys and girls increased their average. This shows that the program was not working better for the boys or the girls. This is in contrast to other researches that found boys being better in mathematics than girls, and progressive faster year by year (Kyriakides, 1999a).

This incompatibility of the results of my research with other researches might be because the whole program I followed is more suitable for both and girls in contrast to daily mathematics activities or it is due to the fact that the sample of the pupils was not representative and very small. The first explanation seems to me closer to the truth but it needs further research to verify it.

Further, there are no well-known researches that studied the differences between boys and girls when using computer software to accomplish certain tasks. Nevertheless as a participant observer, I noticed that boys tended to handle the computer as a game. As a result, while working on certain tasks, they were trying to 'play' by formatting the borders of the tables and adding colour to the boxes. Of course, the colour together with the sound and the immediate response, are advantages the computer offers and attracts people. Girls tend to work more efficiently when using the computer instead of playing.

Ability

Ability cannot be considered as a variable to this study because all twelve pupils were of high ability, according to the records kept at the school (see Chapter 3, p. 60). Pupils were not selected and they joined this group voluntarily. Pupils of low ability did not express any wish to join the group. A reason might be that they were not feeling comfortable that they would be able to keep up with the others - since every pupil knows each other's ability. In addition, they might feel that they would not be able to follow the demands of the lessons. This raises a big issue. Will the coming introduction of computers add the fear of the unknown to pupils and parents?

Although the participation of pupils of high ability in this research can be considered as an advantage the quantitative data do not support this view. Results from the three tests lead us to the notion that computers might be more suitable to less able pupils. Further to this, it is evident that further research is needed to see how single ability groups react in front of the computer compared to mixed ability groups. Comparison of these groups can give us important insights to the use of computers.

II. Limitations of the Study - Methodological Issues and Further Research

This section is intended to examine critically the research and to propose some further steps that could be taken to eliminate the limitations the research has.

The first issue I would like to comment on is the 'origin' of the group. When I started the research, I was planning to work with my morning class (age 11 years old) during the mathematics time. For the computer skills that pupils would need to use the spreadsheet

we would use some time from the Design & Technology Lesson. After the first lesson I realised that it would be impossible to work during the morning lessons; if doing so I would face a major problem by not being able to teach all the units that the mathematics curriculum requires to teach by the end of the school year. Although this change seems to be my decision, it was taken after acknowledging the pressure from the system and more specifically from my Principal and from my Inspector. The Cyprus Educational System is highly centralised and this is mirrored in every school's life from the role of the Principal and the school Inspector.

Although there are positive results in using a spreadsheet to develop problem solving skills the time required is a major theme to be discussed. Can we implement computers as a tool under today's curriculum structure? It can be argued that we need to make changes to the structure of the mathematics curriculum and in other subject areas like Geography and Science in order to promote the use of computers for implementing specific skills related to the whole curriculum.

However, being a teacher in a centralised schooling system, does not allow me to impose any such changes though this is the excuse of every teacher who complains about the system. Nevertheless, the implementation of a "whole-day" approach may help bring about change at the level of the individual schools.

Further to this problem is the formation of the group. The pupils who joined the group were pupils above the average (see Chapter 3, Page 60) and as a result pupils who felt confident to join such group. If I were to work with my class then the team would be consisting with pupils of all groups thus, I could find out whether specific groups of

pupils would gain value from the use of spreadsheets, like early years children, under-achievements, children with special needs, and typical for their age. Moreover, working with pupils of all groups could help to find out which aspects of the curriculum are more appropriate for each group to be taught using a computer and whether positive results are transferred to the wider school context. Grouping is important as stated also in the UNESCO (1997) report with suggestions for single or mixed ability grouping.

Another limitation of the study is that it was not possible to measure the difficulty of the two tests, the pre-test and the post-test. These two tests are curriculum-based tests and I did not use any standardised tests since there is no standardised test in Cyprus. However, the use of a curriculum-based test might be more appropriate and useful for the classroom teacher who wants to have a clear image of his/her classroom. Although the two tests were similar, perhaps I should have used the same test in both cases so that the analysis of the results would be easier since we would compare the same things in different situations, before and after the study.

Another comment on the case study is that after the seven lessons program pupils stopped using the computers to solve problems. If I were to undertake the research again I would find out whether both pupils continuing on the project and those no longer using it would sustain the learning gains in problem solving skills over a further period of time. However, results from the post post-test given one year after the end of the project to all the pupils who took part in the project did not reveal any statistically significant differences.

If the study is repeated it would be important to measure also the change of pupils' attitudes towards mathematics and semi-structured interviews or questionnaires could be used for selecting data. This could measure the effect of positive or negative attitudes towards a specific aspect of the curriculum and suggest ways of improvement. Further to this research, we need to examine the educational gains against costs involved in implementing computers in education and buying software so expensive as MS-Excel 5.0.

We need also to work on another two factors. First is, whether problem-solving skills learned during the program were being transferred to other areas of the pupil's work and second, whether there were gains in computer literacy. The three tests conducted did not examine any computer skills. Perhaps if the study was repeated, it could measure how far a volunteer group succeeded in contrast with a non-volunteer group. In addition, during the project, many pupils have shown an increase in responsibility in managing their learning. Another researcher could examine whether other strategies are more effective in developing independent learning.

If we try to put these activities in the regular program, we need to find (a) the time to teach computer skills, (b) the time to incorporate these exercises in the daytime mathematics schedules. A possible solution to this is to implement computers as a learning tool itself from the younger grades (ages 6 to 9 years old) so that pupils by using simple programs can gain computer skills. With one teaching period every week (40 minutes) pupils will acquire the skills needed for using the computer software. In the later stages, 10 to 12 years old, pupils can use software applications for developing higher levels of learning, in line with Bloom's taxonomy (Bloom, 1956).

Colleagues who use computers as a means for teaching share these views, because the most difficult thing they face is when to teach the pupils the skills to use more sophisticated and complicated programmes like Word-Processors, Spreadsheets and Data Bases. They consider time as the main disadvantage of using computers. This raises the question whether using pencil and paper will help pupils more.

Further to these, as discussed earlier in Chapter 2 there are various models for implementing computers e.g. whole-class model, one-to-one model and computer labs. This case study took place in the computer lab of the school, a setting with advantages and disadvantages. This setting raises questions regarding the external validity of the research, for example the ecological validity. What I would suggest further to get the most from using the computer as a tool, which is the major concern of this research, is to place the computer at the back of the classroom where groups of two or three pupils can work on problem solving activities, while the rest of the class will be doing similar activities.

Another factor that will need further research is what other skills a pupil develops during using software like a spreadsheet program and how these skills are transferred to other subjects' areas. The answer to this can help to reduce the stress from teachers who use computers in their classes and consider computers as too time consuming. When most of the factors are considered, the presentation of the subject is very easy and a simple task in the hands of an experienced and able teacher.

Although the project was taking place after the school time, we need to consider also the opinion of the rest of the teachers of the school and the school principal.

The three types of teachers mentioned earlier in the Literature Review Chapter (see page 35) were found also in my school when I started the project. What I believe is that teachers do not have to be computer literate in order to use a spreadsheet in their teaching. They only need to be familiar with the program, the problem solving literature and understand and value the educational uses of the computer. The right teacher to work with the pupils is the same teacher who teaches them everyday mathematics and may be other lessons. He/she knows the pupils with their strengths and abilities.

A need emerges for further research on how an innovation is influenced by the attitudes of the people who are involved. How does a teacher's behaviour affect problem-solving achievement?

III. Policy Implications and Future work

A. Introduction

After acknowledging the limitations found in this study, I continue in this section with implications for reform based on technological changes and future research derived from the discussion of the findings.

Political leaders, educators, employers, and the public are expressing an unprecedented level of concern with the state of education in Cyprus, especially with the ongoing structured dialogue between the Republic of Cyprus and the European Union and the need to harmonise our educational system with that of the EU members. Furthermore, there is an ongoing pressure in the media for educational reform, especially after the comparatively poor performance of Cypriot Pupils in international tests (Mullis et al, 1997; Campbell and Kyriakides, 1998).

Over the last years, we have seen a proliferation of education reforms. Most prevalent was the writing of The New Curriculum in 1994 with a subsequent change of the textbooks in some curriculum subjects like Mathematics, Geography, English and Home Economics. Furthermore, an effort was given to change the status of Design and Technology lesson by separating it from the Home Economics. Although these changes meant a change also in the instruction, they occurred without any substantial change in the nature of teaching (Kyriakides, 1999b). Another movement towards educational change was the Implementation of Computers (1993-94) as a tool for learning in thirty-two schools all over the island (9.41 per cent-1999). The research reported here can be seen as an attempt to find out how we can make use of the new technologies in changing the way of introducing certain skills to the pupils. As a result, it contributes to an evaluation of "the computers innovation" by the Department of Education of Cyprus, through examining the impact it has on pupils. This section is an attempt to draw implications of the findings for the policy of introducing the use of computers in primary education.

The multiple levels and component parts of an education system help to maintain the status quo and swallow up piecemeal attempts for reform. It follows that if we want substantial improvements, we will have to undertake fundamental and comprehensive change. Technology is an important tool in bringing about the kind of revolutionary changes called for in these reform efforts. Having seen the ways in which technology has transformed the workplace, and most of our communications and commercial activities, the business community and the public in general are exerting pressure for comparable changes within schools.

Technology is viewed as a means of supporting goals related to increased pupil involvement with complex, authentic tasks and new organisational structures within classrooms and schools (Sheingold, 1990).

The primary motivation for using technologies in education is the belief that they will support superior forms of learning. For this reason, theory and research in learning provide an extremely important source of ideas. Advances in cognitive psychology have sharpened our understanding of the nature of skilled intellectual performance and provide a basis for designing environments conducive to learning. There is now a widespread agreement among educators and psychologists (Collins et al, 1989; Resnick, 1987) that advanced skills of comprehension, reasoning, composition, and experimentation are acquired not through the transmission of facts but through the learner's interaction with content. This constructivist view of learning, with its call for teaching basic skills within authentic contexts (hence more complex problems), for modelling thought processes, and for providing for collaboration and external support to permit pupils to achieve intellectual accomplishments they could not do on their own, provides the wellspring of ideas educational reform.

Currently, we are at a time of great technological advance. Computing power is more available and affordable than ever before. Tools to support computer applications make it possible for school children to do everything from communicating with their counterparts on the other side of the world to building their own curriculum materials in hypermedia formats to collecting and analysing data much as practising scientists would. While the most sophisticated technology remains in the hands of the few, it is becoming increasingly affordable and available. At the same time, we are finding educationally sophisticated

uses of commonplace technologies, such as spreadsheets and word processing. There are enough cases where technology and school reform have been successful partners to tell us that the marriage can be a productive one (Stearns et al. 1991; Zorfass, 1991). On the other hand there are many cases where school districts invested in technology that turned out not to be well used (computers gathering dust in the corner of a classroom), or to be used in ways that merely perpetuated the status quo (e.g., Mechan 1989; Oakes & Schneider, 1984). From the "successes", we have learned that technology often produces unexpected benefits for pupils and teachers (Stearns et al., 1991). From failures, we have learned that implementation without thoughtful planning or sustained support is nearly always in vain (Fullan, 1991). In the current case study, pupils used a spreadsheet to develop problem solving skills and through that higher levels of thinking, suggesting ways of improving the more general use of computers in primary education.

Any reform efforts must look not just at the classroom but also at the whole system within which education takes place. The ultimate goal is to have a beneficial impact on pupils' learning and of course on teachers' instruction, the two major concerns of this research. As a result, they raise questions about Teaching Methods and the Content of the curriculum.

Teaching Methods

The pupil-level outcome goals of most reform efforts are to increase learning, especially of advanced or higher-level skills, and to enhance pupil motivation and self-concept. There are various schools of thought as to how to achieve these ends, but the thinking within this research study was concerned with introducing spreadsheets to develop

problem-solving skills. The work conducted in the computer lab for almost four months stressed the elements shown in the second column of the following table.

Table 1

Comparison of conventional approaches to instruction and using a spreadsheet on a computer to develop problem-solving skills.

* Conventional Instruction	* Spreadsheet Instruction
* Teacher-directed	* Pupil exploration
* Didactic teaching	* Interactive modes of instruction
* Individual work	* Collaborative work
* Teacher as knowledge dispenser	* Teacher as facilitator
* Ability groupings	* Heterogeneous groupings

(Means, Blando, Olson, Middleton, Cobb, Remz, & Zorfass, 1993, p. 2)

The use of computer in the classroom forced a movement from the 'conventional instruction'; pencil and paper to 'spreadsheet instruction'. Further to this, the teacher-directed approach during this project became pupil exploration. Faced with problems to solve, pupils took a more active part in defining their own learning goals and regulating their own learning. Pupils explored ideas and bodies of knowledge, not for recall of facts on demand, but to understand phenomena and find information they need for their work. When working on complex tasks, pupils` work will often cross over the borders of academic disciplines, just as real-world problems often demand the application of several kinds of expertise. In this context, didactic teaching becomes interactive. The nature of the information and the support provided for pupils change depending on what pupils do; the problems they work on can change and evolve over time.

Technology and reform do not necessarily go hand in hand. Procedures for this innovation have been very careful, to avoid examples provided by studies of specific sites that invested in technology with the idea of changing the school or the classroom, only to find that the equipment sat in a closet or that teachers used the technology to do the same things they had always done (Oakes & Schneider, 1984). At the same time, the majority of school reform efforts are proceeding without any appreciable contribution from technology.

Nevertheless, studies of instructional uses of technology over the past decade have taken a new turn, showing not just whether a technology can teach or how it compares with conventional instruction but the effects that technology has on what is learned and the teaching and learning roles within the classroom. What this literature shows, in brief, is that when used in ways that are compatible with the pupil learning model shown as the second column of Table 1 page 110, technology supports exactly the kinds of changes in content, roles, organisational climate, and effect that are at the heart of the reform movement.

Exploratory uses of instructional technology allow pupils to direct their own learning. Through the process of discovery, or guided discovery, the pupil learns facts, concepts, and procedures. Exploratory uses of technology tend to deal with complex learning activities. Such uses of technology are very congruent with the goals of education reform. One of the most significant shifts in the way that technology can be used in education today is toward greater use of computers and other devices as tools in the learning process rather than as instructional delivery devices. Such uses mirror the ways in which technology is used in the workplace and at home. Spreadsheet applications, word processing, desktop publishing, database and, drawing, painting, and graphing programs

are examples of technology tools. Whenever pupils manipulate data in a spreadsheet, compose using a word processor, spell check their composition, use an on-screen calculator or graphing program, look up information in a database, or publish a classroom newspaper, they are using computers as tools.

Using technology as tools solves a major problem that frequently arises, in discussions among teachers, in the use of technology for tutorial or exploratory uses--that of the technology's curriculum not being consistent with the teacher's curriculum. Often, tutorial or exploratory products that are interesting in their own right do not have a place in a given school's course of study. Further to this, it solves a major problem we face in Cyprus. The great majority of the software found in the market is in English. To change the codes and translate them in Greek require substantial money and time. In contrast, when technology is used as a tool, the teacher can still control the curriculum and the instructional strategy. The technology merely provides pupils with aids for studying that content or practising those skills. Tool products can be applied in a variety of curricular activities: spreadsheets for problem solving; word processors for writing and revising assignments, graphing programs for mathematics instruction, desktop publishing systems for producing newspapers, and hypermedia systems for development of one's own study materials. Technology tools are designed to facilitate educational and work-related tasks. They are flexible, lending themselves to a wide variety of activities across the grade levels and throughout the curriculum. We have seen the curriculum being used as the means to teach certain computer skills and not vice versa. From an education reform perspective, this flexibility is both a strength and a weakness. Whether technology tools are applied in ways that promote traditional instruction or education reform is dependent on the perspective, skills, knowledge and practices of the classroom teacher.

B. Collaborative work

These complex tasks also lend themselves to collaborative work. Pupils worked through mathematics problems as a group in front of a computer. There are many advantages of collaborative learning. In the process of collaborating, pupils gained experience in negotiating the purpose of their work and the meaning of the terms they use, by following the four-step method of Pólya. These experiences mirror the activities of professionals working together. Collaborative work also has advantages in terms of motivation: pupils get involved because they like to work together; further, if difficulties encountered by either the use of the computer or the spreadsheet, are temporarily daunting to one pupil, another pupil's enthusiasm could carry the work forward. Another noted advantage for collaboration around a computer is the fact that it calls on pupils to justify their conclusions and to act as external critics for each other. In so doing, they become more reflective about their own thinking. Over time, pupils will come to internalise the role of critic so that they can act as critic for their own work. This collaborative project facilitated adjusting tasks to accommodate individual differences. Pupils of different ability levels can work together, taking roles correspondent with their skills. Thus, it becomes feasible to teach heterogeneous groups of pupils who vary in age, expertise ability levels, and so on. Within such groups, the experience of explaining something to a fellow pupil who does not understand it can in itself be educationally valuable.

Pupils formed their groups on their own. There were no mixed groups, with both boys and girls. The disadvantage of having the boys dominate girls was eliminated.

There were times that a pupil was trying to take over what was happening in the group. This pupil was either a more able student (although the ability range was not great) who

was getting bored or anxious or a less able student who was trying to play with the computer. This challenged the work of the teacher who must be ready to give a variety of activities to the pupils to keep their interest, not too easy and not too difficult, with real world problems for boys and girls.

C. A change in teacher's role

Within this learning model, the teacher becomes a facilitator and a "coach" rather than a knowledge dispenser or project director. Teachers are responsible for setting up the problems and creating the organisational structure within which groups do their work, but once work begins, teachers no longer have the total control of the direction of instruction that they exercise in conventional classrooms. It seems natural here for a movement towards a change of the role of the teacher but we cannot demand for a change of every teacher's role and style.

The introduction of computers for problem solving as an educational improvement requires resources, most notably time for teachers to plan and develop programs and to receive and provide training in their implementation. This translates into money and time and one of the major ways in which higher levels of the system can contribute to reform is through provision of resources. These levels also provide technical assistance and opportunities for training teachers and administrators. Further to this, we need to change teachers' attitude towards the use of computers for teaching. It is true that although this research has shown that pupils benefit from the use of a spreadsheet to develop higher levels of thinking, it does not allow us to dispense with pencil and paper.

In the new 'Five-year Plan for the Introduction of Information Technology in Primary Education' (Department of Primary Education, 1999) it is proposed as far as the training of the teachers in using computers to be in three levels: Pre-service, at the University of Cyprus, from the Pedagogical Institute for the in-service teachers and at the school level with "on-the-job" training. A serious disadvantage is that being myself the teacher (an Information Technology Coordinator) and the researcher I could not measure how the teacher' s enthusiasm affected pupils' progress. Although there are studies in Cyprus that measured positive teachers' perceptions for the introduction of computers in primary education (Kanaris et al, 1995), there are none measuring how teachers' perceptions change as they are working with computers in their classrooms. It is a different matter to agree with the introduction of an innovation in education, from working with that change, something that my research did not measure or was not able to measure.

Content

A problem, according to Instone (1988) is:

> "A difficult situation that possesses two features: an objective and an obstacle. Without both features, it is merely a task. However, even a task can be better tackled with developed thinking skills." (p. 63)

Therefore, problem-solving aims to find a way where no way is known from previous knowledge, to find a way out of a difficulty, to find a way around an obstacle, to attain a desired end, that is not immediately attainable, by appropriate means (Pólya, 1949).

Thus, problem solving involves thinking, and more precisely two kinds of thinking: creative (divergent) and critical (analytical) (Fisher, 1990). Further, problem solving

involves 'intellectual curiosity'. It is seeking to find answers to questions, ways to overcome difficulties, solutions to puzzles and ways of accomplishing goals. The problem-solving attitude is a part of the person's personality (Flake et. al, 1990).

Hence, problem solving is better tackled if people's ability to think is developed. Thinking is a skill, and like all skills, the more one practises it, the better he/she will become at it. An awareness of all the different thinking strategies and an ability to use them, having practised them in cross-curricular situations (including Mathematics) can improve children's ability to solve problems (Instone, 1988).

There is an implicit need for curriculum change. As mentioned earlier under a centralised school system it is very difficult for a teacher to implement major changes. Now that the introduction of computers has been announced as a part of the 'whole-day school' it would be the right time to implement the use of problem solving as a cross curriculum object. Furthermore, the introduction of a new skill as the use of computers calls for more changes in the curriculum as a whole and not strictly to the use of computers in the mathematics' curricula.

D. Teaching and Learning with Spreadsheet Technology: A synopsis

Changes are occurring at an accelerating pace in society and economy. These rapid changes are creating demand for well-educated people. Research is changing education by providing useful new insights into how pupils learn while new technologies are transforming communication and information.

In the past decades, school dropouts could get good jobs in factories and in business. Today, in many jobs, a Lyceum diploma is not enough for employment. Although in the Cypriot society until recently people very rarely changed career many will have to change careers several times during their lifetime. In addition, many jobs require advanced knowledge, technological skills, and ability to continue learning and adapting to changing times.

Our educational system was made for simpler times. Today we need more than reading, writing and arithmetic. Pupils need to know how to find and use new information, make informed decisions about complicated issues and above all to learn how to learn. These new insights call for a change on how we teach and how pupils learn. There is a call for changing the face of education. Education needs to reflect changes in society and the economy, in the new ideas of what education should become and have the ability to incorporate technology to assist in teaching and learning.

We as teachers have common goals for our pupils. As teachers, we use a variety of methods to achieve these goals. The teacher's role is as transmitter of information with pupils being the passive recipients of information. The classroom as a small society is well organised, disciplined, and predictable. This change will transfer teacher to a facilitator, pupils will become more active and we will have an active, changing and collaborative classroom.

The Cypriot Education System is extremely centralised and as a result, if any changes will occur they happen at a very slow pace heavily affected by bureaucracy. In addition, many teachers are reluctant to change for several reasons. The current model is working for

them and this is how they see the world. Further, constructivism is more ambiguous and amorphous than knowledge-transmission system.

Technology is always changing. Throughout the history, technology has been seen as a way to allow people do things better. Archimedes 346 BC being excited on the use of the lever said, "Give me where to stand, and I will move the Earth". The newly appointed Minister of Education and Culture, Mr. Ouranios Ioannides, in a newspaper interview (Kreouzos et al., 1999) listed several points on what kind of pupil should graduate from schools, perceiving that critical thinking is not developed in schools:

> A citizen with a critical mind who can keep what he should and reject whatever is useless.
> He/she is well versed in the use of computers.

In addition, Ministry officials and teacher's organizations agree with the philosophy that computers should be used as a tool in all subjects to enhance the learning process. This study has shown that the pupils who used spreadsheet technology for problem solving had increased motivation, absentee rate at the workshops was very limited or did not exist. More importantly, pupils changed the way they did their mathematics and the teacher changed his/her teaching.

Schools can benefit from the constant changing of technology. Hardware has become less expensive, faster, smaller and more pervasive. In the near future technologies will be more integrative, more interactive with distance learning opening the classrooms to greater work across distances, and greater control over what is learned. Added to this, technologies will be more intelligent giving to the users access to more databases and networks, while technologies will be learning from the user.

All these lead to a very critical question. What do we want for our pupils? We want our pupils to solve problems and make decisions, master basic skills, be motivated to continue to learn, be good critical thinkers, and have social skills. Teachers to achieve these goals need to use a variety of strategies to help pupils reach these goals. Teaching with technology is one of the ways to help pupils through discussions, co-operative learning, simulations, demonstrations, independent research, etc.

To start using technology in our school we must first create a school technology plan and be prepared to integrate computers into all subjects. At the same time, we must increase teacher in-service training on the effectiveness of the use of technology and how to use the technology. Even if we have the finest facilities if the teacher is not computer literate and motivated to use technology then nothing will happen. We must help teachers to feel ownership of the change, believe change is supported by the central office, believe change will help them do their job better, value the outcome of the change, realise their security is not at risk, recognise that change reflects their values, help determine the problem that initiated change, and accept change through consensus.

One of the challenges I faced at the beginning of the research was the time to allocate for the pupils to learn basic skills of the software. This fear made me change the group of the pupils and instead of working at school time we were working in the afternoons after the bell rang. Although the research has shown positive effects on pupils' learning it could be argued that all this is in vain, if we are to bring pupils after school to help them use computers as a tool. We must get computers into the classroom. One computer in 20 rooms is better than 20 in a lab, if it is used creatively.

What is needed from the use of spreadsheet technology:

It can help with the following objectives:

- Knowledge of facts
- Comprehension for understanding
- Application of information
- Analysis of critical components
- Synthesis into new structures
- Evaluation of systems

What is not needed from the use of spreadsheet technology is:

- Technology should not be seen as support for poor teaching.
- Technology should not substitute the teacher
- Replace the pencil and the paper.
- Change the classroom from a live community to an office setting.

There is no one 'right way' to use technology. In addition, we know that not all teachers and administrators will embrace using technology. However, if technology is to do repetitive tasks, to reinforce didactic roles and information provider it is better not to use. Technology is to change education, engage pupils in their learning, help school reflect society, become a facilitator of learning, expand pupils' worlds, then we can consider computers to develop higher levels of thinking.

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INSTITUTE OF EDUCATION

"THE USE OF SPREADSHEETS AS A TOOL FOR THE DEVELOPMENT OF PROBLEM SOLVING SKILLS IN THE MATHEMATICS CURRICULUM IN A PRIMARY SCHOOL IN CYPRUS"

CHAPTER 7: APPENDICES

INSTITUTE OF EDUCATION

I. APPENDIX A: Letters

a) Letter to the District Education Office asking permission for conducting the research (in English and Greek)
b) Letter to parents (in English and Greek)

S.I. No ****
F. No. **

*****
****
Christos Papadopoulos

15 November 1996

District Education Office
Lemesos

Chief Education Officer
Mr. Christos Combos

Dear Sir,

As you are already aware our school is a member of the Experimental Schools for the Implementation of Information Technology into the Primary Education as a Tool for Teaching. Through this scheme we are planning to use Spreadsheet Software into the teaching of mathematics curricula, at the Sixth Grade.

The work is a part of my Postgraduate Studies' Research at Warwick University (United Kingdom). The title of the research is "THE USE OF SPREADSHEETS AS A TOOL FOR THE DEVELOPMENT OF PROBLEM SOLVING SKILLS IN THE MATHEMATICS CURRICULUM IN A PRIMARY SCHOOL IN CYPRUS".

The Parents' Association will donate the software we are going to use. This software will be used by the Adult Education Centre that is using the Computer Lab in the evenings as well as by the Pedagogical Institute of Cyprus that is going to use our facilities for Computer Lessons to teachers in the afternoons.

Waiting for your approval.

Sincerely,

Christos Papadopoulos
(Teacher)

I' am knowledgeable of the letter.

This is a phrase used when a teacher is sending a letter to the Ministry with the Headmaster's awareness.

Charalambos Charalambides
Principal

ΑΚΑ 419045
Π 5486

*****
****
Χρίστος Παπαδόπουλος

15 Νοεμβρίου, 1996

Επαρχιακό Γραφείο Παιδείας & Πολιτισμού
Λεμεσός

Πρώτο Λειτουργό Εκπαίδευσης
κ. Χρίστο Κόμπο

Αξιότιμε κύριε,

όπως γνωρίζετε το σχολείο μας αποτελεί μέρος των Πειραματικών Σχολείων για την Εισαγωγή των Ηλεκτρονικών Υπολογιστών στη Δημοτική Εκπαίδευση ως μέσο διδασκαλίας. Μέσα στα πλαίσια του προγράμματος αυτού σχεδιάζομε τη διδασκαλία και χρήση ενός προγράμματος 'Λογισμικών Φύλλων' στο μάθημα των Μαθηματικών.

Η όλη εργασία θα γίνει μέσα στα πλαίσια Μεταπτυχιακού Προγράμματος που παρακολουθώ στο Πανεπιστήμιο Warwick (Αγγλίας) με τίτλο "THE USE OF SPREADSHEETS AS A TOOL FOR THE DEVELOPMENT OF PROBLEM SOLVING SKILLS IN THE MATHEMATICS CURRICULUM IN A PRIMARY SCHOOL IN CYPRUS".

Το Λογισμικό που θα χρησιμοποιηθεί θα αγοραστεί από το Σύνδεσμο Γονέων του Σχολείου, ώστε να χρησιμοποιηθεί και από τα Επιμορφωτικά Κέντρα του Υπουργείου Παιδείας & Πολιτισμού που οργανώνουν νυκτερινά μαθήματα Η.Υ. στο σχολείο μας, καθώς επίσης και από το Παιδαγωγικό Ινστιτούτο Κύπρου το οποίο θα χρησιμοποιήσει φέτος το σχολείο μας για την επιμόρφωση των δασκάλων στους Η.Υ. .

Παρακαλούμε για την έγκρισή σας.

Με εκτίμηση,

Χρίστος Παπαδόπουλος
(Δάσκαλος)

Έλαβα γνώση:

Χαράλαμπος Χαραλαμπίδης
Διευθυντής

******

TEL. ******

28 March 1997

Dear Parents,

Subject: *Use of Computers as a means for teaching*

As you are already aware our school is taking part in one of the most innovative changes in Primary Education with the introduction of computers as a tool for teaching.

Through this scheme we are planning to use Spreadsheet Software into the teaching of mathematics curricula, at the Sixth Grade The philosophy of the program is the unbiased introduction of computers into the school program as another tool in the hands of the teacher and not as a new curricula. The required skills needed for working with the computers will be developed through the work on simple software programs like painting and mathematics.

Through this scheme I am conducting a research about **"Using a spreadsheet for the development of problem solving skills"**. The results of the research, positive or negative, will give us the gears for the right use of the new technology.

During the case study pupils will work on two tests. One at the beginning (pre-test) and one at the end of the research. Pupils will be working on a series of activities on the computer.

The research has been approved by the District Education Office and will be held during the afternoons after school time. It is going to be a part of the computer lessons your children are attending in the afternoons but there will be no fees. After the end of the research and the analysis of the results you will be informed in a parents' evening about the results.

For more information you can visit me at school every Monday between 12.25p.m. to 13.05 p.m. People who do not want their children to take part in the research can inform the school and their wish will be accepted.

Thank you,

Christos Papadopoulos
(Teacher)

Charalambos Charalambides
(Principal)

******

τηλ. ******

28 Μαρτίου, 1997

Αγαπητοί γονείς,

Θέμα: *Χρήση των Ηλεκτρονικών Υπολογιστών ως μέσο διδασκαλίας*

όπως σας είναι γνωστό τα τελευταία τρία χρόνια το σχολείο μας λαμβάνει μέρος στην εφαρμογή μιας από τις πιο ριζοσπαστικές καινοτομίες που έγιναν στη Δημοτική Εκπαίδευση με την εισαγωγή των Ηλεκτρονικών Υπολογιστών ως μέσο διδασκαλίας.

Η φιλοσοφία του προγράμματος είναι η φυσιολογική ένταξη των Η.Υ. στο σχολικό πρόγραμμα σαν ένα ακόμα εργαλείο στα χέρια του δασκάλου και όχι σαν ένα καινούριο μάθημα. Οι απαιτούμενες δεξιότητες χρήσης των Η.Υ. αποκτιούνται αβίαστα με την ταυτόχρονη εκμάθηση συγκεκριμένων προγραμμάτων όπως Μαθηματικών και Ζωγραφικής.

Μέσα σε αυτά τα πλαίσια διεξάγω έρευνα για τη "**Χρήση του Ηλεκτρονικού Υπολογιστή στην απόκτηση δεξιοτήτων στη λύση του μαθηματικού προβλήματος**". Τα αποτελέσματα, όποια και αν είναι αυτά, θα μας δώσουν τα εφόδια για ορθότερη αξιοποίηση της νέας τεχνολογίας.

Κατά τη διάρκεια του προγράμματος τα παιδιά θα λύσουν δύο Διαγνωστικά Δοκίμια, ένα στην αρχή (pre-test) και ένα στο τέλος (post-test). Κατά τη διάρκεια του προγράμματος τα παιδιά θα εργάζονται σε μια σειρά δραστηριοτήτων με τη χρήση των Η.Υ..

Η έρευνα αυτή είναι εγκριμένη από το αρμόδιο τμήμα και θα διεξάγεται κατά τη διάρκεια των Μαθητικών Λεσχών που θα συνεχίσουν πέραν των 15 ενενηντάλεπτων μαθημάτων, χωρίς να πληρώσετε περισσότερα λεφτά. Με το τέλος της έρευνας και την ανάλυση των αποτελεσμάτων θα γίνει ενημέρωση όλων των γονιών.

Για περισσότερες πληροφορίες μπορείτε να με επισκεφτείτε στο σχολείο κάθε Δευτέρα από τις 12.25 μέχρι τις 13.05. Γονείς που δεν θέλουν τα παιδιά τους να λάβουν μέρος στην έρευνα αυτή, μπορούν να ειδοποιήσουν το σχολείο και η επιθυμία τους θα γίνει αποδεκτή.

Ευχαριστώ,

Χρίστος Παπαδόπουλος
Δάσκαλος

Χαράλαμπος Χαραλαμπίδης
Διευθυντής

INSTITUTE OF EDUCATION

II. APPENDIX B: A list with the problems that were used during the Case Study

Introductory Lesson:

By using the digits 1 to 9 without repetition create a square 3X3 so that all row sums and column sums equal 15.

Lesson 1:

A person paid £1,55 giving 19 coins of 5s, 10s and 20s. How many coins of each did he/she give?

Lesson 2:

Ten triangles and squares have 36 sides. How many of them are the triangles and how many are the squares?

Lesson 3:

If 110 Kg of sugar is distributed in 31 bags of 5kg and 2kg, how many of each bags of each size were used?

Lesson 4:

A floweriest has carnations that are more than 50 and less than 100. If she makes bouquets of 10, 4 carnations are remaining and if she makes bouquets of 7 nothing remains. How many carnations are there?

Lesson 5:

Mary makes cups. She makes two sizes: small sizes cup that worth £2,50 each and large size cup worth £5,75 each. Yesterday Mary got £47. How many cups from each size did she sell?

Lesson 6:

In a farm there chickens and rabbits. The heads of all the animals are 20 and all the total of their legs is 54. How many chickens and how many rabbits are there in the farm?

Lesson 7:

Three bells play the first every 15 minutes, the second every 20 minutes and the third every 30 minutes. If they rang all together at 9.30 a.m., at what time will the three bells play together again?

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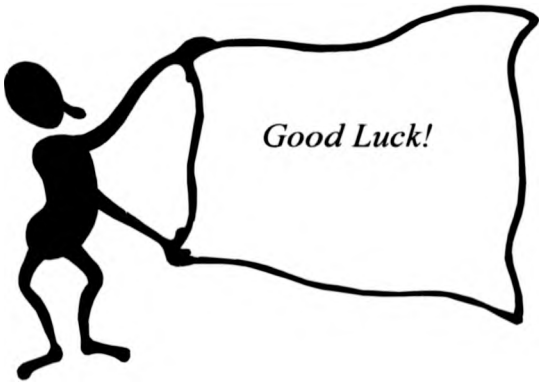
III. APPENDIX C: Pre-test and Post-test (in English)

"School Logo"

Pre - Test

Name: _____



Duration: 80 minutes

March 97
Christos Papadopoulos

PART A

1) Solve all the exercises vertically in the space provided.

a) 487+993 =	f) 674-188 =	k) 780X85 =	p) 7 525÷7 =
b) 8 244+295 =	g) 4 693-2582 =	l) 6X768 =	q) 4 640÷57 =
c) 4 923+7 452+78 =	h) 68 345-7 988 =	m) 9X12,05 =	r) 1 926÷92 =
d) 4,67+2,93 =	i) 56-2,59 =	n) 36X385 =	s) 148÷130 =
e) 7,54+0,99 =	j) 19,45-7,88=	o) 605X380 =	t) 8 950÷435 =

2) Write the following numbers arithmetically:

Two hundred fifteen thousands and sixty four: _____

Three millions twelve thousands one hundred five: _____

3) How bigger is the value of digit A from digit B?

385 259

A B

_____

4) What is the value of the digit 6 in the number 463 287;

_____

5) Solve the following patterns:

_____, 9 999, _____ _____, 100 000, _____

6) Write the following numbers in order starting with the biggest:

1/3 1/2 ¾ 2/3 0,5 5/9 1 2/5 1 1/3 1 3/10

_____ _____ _____

7) Put the right symbol < or = or > in every circle.

a)	906	◯	960	f)	6/8	◯	¾
b)	65 382	◯	65 379	g)	1/3	◯	4/9
c)	73 000	◯	72 999	h)	12,5	◯	12,54
d)	832 000	◯	8 320	i)	1/2	◯	0,5
e)	506 735	◯	6 673	j)	0,7	◯	0,69

Part B

Solve all the problems in the space provided.

Problem 1

If every pupil in a class pays £1 for a school trip, there will be £5 less. But, if each pupil pays £1,25 there will be £5 more. How many pupils are in the classroom?

Problem 2

Two balloons and two pencils cost 1 pound. Two pencils and one balloon cost 80c. One pencil and two balloons cost 70c. How much does a pencil and how much does a balloon cost?

Problem 3

A person paid £1,55 giving 19 coins of 5s, 10s and 20s. How many coins of each did he/she give?

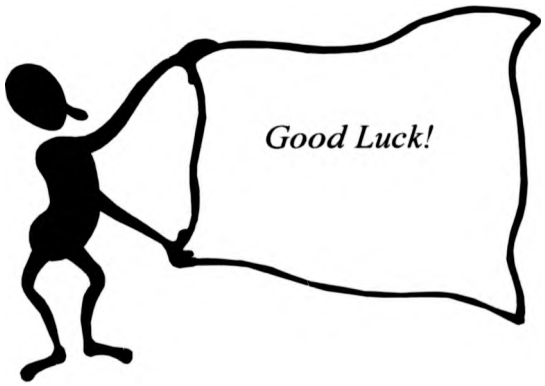
Problem 4

Eleni is 10 years old now and Katerina is 15. A few years ago, when Katerina was twice as old as Eleni, Katerina taught Eleni how to swim. How old was Eleni when she learned to swim?

"School Logo"

Post Test

Name: _____



Duration: 80 minutes

JUNE 97
CHRISTOS PAPADOPOULOS

PART A

1) Solve all the exercises vertically in the space provided.

a) 368 + 852 =	f) 523 - 245 =	k) 650 X 47 =	p) 5 584 ÷ 7 =
b) 9 703 + 406 =	g) 6 781 - 1 582 =	l) 7 X 894=	q) 6 360 ÷ 45 =
c) 1 932 + 8 653 + 36 =	h) 86 445 - 6 755 =	m) 9 X 14,08=	r) 1 723 ÷ 54 =
d) 5,48 + 2,04 =	i) 5,45 - 3,56 =	n) 23 X 689 =	s) 215 ÷ 124 =
e) 3,64 + 0,78 =	j) 12,32 - 3,45=	o) 406 X 890 =	t) 7 650 ÷ 325 =

2) Write the following numbers arithmetically:

Three hundred thirty five thousands seventy three: _____

Two millions fifty three thousands two hundred eight: _____

3) How bigger is the value of digit A from digit B?

217 174

A B

_____

4) What is the value of the digit 2in the number 728 653;

_____

5) Solve the following patterns:

_____, 8 999, _____ _____, 10 000, _____

6) Write the following numbers in order starting with the biggest:

1/4 1/5 2/7 2/3 0,6 5/8 1 1/3 2 1/5 1 7/10

_____ _____ _____

7) Put the right symbol < or = or > in every circle.

a)	802	◯	820	f)	6/8	◯	3/4
b)	72 453	◯	72 543	g)	1/4	◯	3/8
c)	53 000	◯	52 999	h)	15,6	◯	15,59
d)	564 000	◯	5 640	i)	1/4	◯	0,25
e)	405 458	◯	5 854	j)	0,4	◯	0,39

Part B

Solve all the problems in the space provided.

Problem 1

Nikki is gathering soda coupons that she finds in soda bottles. There are two kinds of coupons: 5 points coupons and 2 points coupons. Up to now she has gathered 23 coupons equal to 76 points. How many coupons of each kind did she gather?

Problem 2

The pupils and the Parents' Association are presenting the 5th Talent Evening in the School Theatre. Katie is selling entrance tickets. Pupils' tickets are 50c each and adults' tickets £2,00 each. Her total takings were £250. How many pupils and how many adults entered the School Theatre?

Problem 3

All the pupils of a school can stand in lines of three, five or eight. How many pupils does this school have if you know that they are less than 500 and more than 400 hundred.

Problem 4

Using the digits 1 to 9 create three three-digit numbers whose sum is 999. You can use each digit only once.

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IV. APPENDIX D: Analysis of tests

Table 1: Four Operations, Addition, Subtraction, Multiplication and Division (Exercise 1)

	Addition		Subtraction		Multiplication		Division		total	total
	pre-test	post-test	pre-test	post-test	pre-test	post-test	pre-test	post-test	pre test	post test
S01	5	5	5	4	2	2	4	5	80	80
S02	5	5	4	4	4	4	4	3	85	80
S03	5	5	4	5	3	4	4	4	80	90
S04	4	4	5	5	5	4	4	5	90	90
S05	5	5	2	5	5	5	5	5	85	100
S06	4	4	4	5	4	4	3	3	75	80
S07	5	5	5	4	2	5	2	2	70	80
S08	5	5	4	4	5	5	5	2	95	80
S09	5	5	5	4	3	4	2	1	75	70
S10	5	5	3	5	5	5	2	5	75	100
S11	5	5	5	5	4	4	4	5	90	95
S12	5	5	4	5	5	5	5	5	95	100
Average	4.83	4.83	4.17	4.58	3.92	4.25	3.67	3.75	82.92	87.08
StDev	0.37	0.37	0.90	0.49	1.11	0.83	1.10	1.42	8.02	9.67
t-score									-1.10	

Table 2: Place Value - Fractions & Decimals.

	Place value 2-5,7a-e pre-test	post-test	total pre-test	total post-test
S01	9	9	69.23	69.23
S02	7	8	53.85	61.54
S03	12	11	92.31	84.62
S04	10	11	76.92	84.62
S05	12	13	92.31	100.00
S06	11	12	84.62	92.31
S07	7	7	53.85	53.85
S08	13	12	100.00	92.31
S09	9	8	69.23	61.54
S10	12	12	92.31	92.31
S11	12	12	92.31	92.31
S12	11	12	84.62	92.31
Average	10.42	10.58	80.13	81.41
StDev	1.93	1.93	14.88	14.88
t-score			-0.20	

	Fract. & Dec. 6,7f-j pre-test	post-test	total pre-test	total post-test
S01	4	5	50.00	62.50
S02	4	3	50.00	37.50
S03	7	5	87.50	62.50
S04	6	7	75.00	87.50
S05	6	5	75.00	62.50
S06	6	5	75.00	62.50
S07	4	4	50.00	50.00
S08	5	5	62.50	62.50
S09	3	3	37.50	37.50
S10	7	4	87.50	50.00
S11	7	6	87.50	75.00
S12	6	8	75.00	100.00
Average	5.42	5.00	67.71	62.50
StDev	1.32	1.41	16.50	17.68
t-score			0.71	

Table 3: Part B - Problems.

	probl.1 pre-test	probl. 1 post-test	probl. 2 pre-test	probl. 2 post-test	probl. 3 pre-test	probl. 3 post-test	probl. 4 pre-test	probl. 4 post-test	total pre-test	total post-test
S01	0	1	0	0	0	0	0	3	0.00	33.33
S02	0	3	1	1	0	2	0	3	8.33	75.00
S03	0	3	3	0	3	2	0	3	50.00	66.67
S04	0	3	3	2	3	2	3	3	75.00	83.33
S05	0	3	3	2	3	2	3	3	75.00	83.33
S06	0	3	0	0	0	0	3	2	25.00	41.67
S07	0	3	3	2	3	2	3	2	75.00	75.00
S08	0	3	3	0	3	0	0	2	50.00	41.67
S09	0	3	3	1	1	2	0	3	33.33	75.00
S10	0	3	3	3	3	2	3	3	75.00	91.67
S11	0	3	3	3	3	3	3	3	75.00	100.00
S12	0	3	0	3	0	3	3	3	25.00	100.00
Average	0.00	2.83	2.08	1.42	1.83	1.67	1.75	2.75	47.22	72.22
StDev	0.00	0.55	1.32	1.18	1.40	1.03	1.48	0.43	27.07	22.93
t-score									-2.34	

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V. APPENDIX E: Data Collection Sheet & Data Collection Sheet Sample

Data Collection Sheet No…

Problem & Strategy:

Date & Time

Number of participants

General Observations

Group working

Who has involved?

What issues were covered or not covered?

Technical issues

Relevance to research questions

Do spreadsheets as a Computer Assisted Instruction (CAI) application improve learning and teaching in problem solving activities?	
In what ways do spreadsheets as a Computer Assisted Instruction application influence pupils' achievement in solving problems?	
Are there variations in the effectiveness of Spreadsheets as a Computer Assisted Instruction application among different types of pupils?	

New hypotheses suggested & Implications for subsequent data collection:

Group 1	**Group 2**	**Group 3**
Group 4	**Group 5**	

List of Attachments:

Data Collection Sheet No:

- 5 (Lesson 5)

Problem & Strategy:

- Mary makes cups. She makes two sizes: small sizes cup that worth £2,50 each and large size cup worth £5,75 each. Yesterday Mary got £47. How many cups from each size did she sell?
- Use or make a table, Guess and check.

Date & Time:

- 9th of June

Number of participants:

- 12

VI. General Observations

- **Group working:** Pupils S10 was asked to join Group 3 to help his/her friends. This helped a lot the other two members of his/her Group (1) to take responsibility of the work made in their group. S10 with his/her capabilities was dominating in the group. Pupils in Group 3 were helped a lot with his/her presence in the team especially in the writing of formulas. (FORMATION OF GROUPS, should it be of mixed ability, should I change the groups to include both boys and girls.)
- **Who has involved?**
  - All groups.
- **What issues were covered or not covered?**
  - General aims:

1. Develop the skills necessary to apply their mathematical understandings to recognise, identify, and formulate problems from given practical situations outside the domain of mathematics, as well as from relevant situations within the domain of mathematics. (Look at the situation.)
2. Develop skills in using problem analysis strategies and modelling techniques. (Get to know the problem and decide what to do.)
3. Develop skills necessary to solve problems in all strands of the mathematics program. (Do it.)

4. Develop skills necessary to interpret or evaluate the solution in the original situation, or in an application to a new situation, of a generalisation. (Think about what is done.)

- **Technical issues:**
  - No technical issues emerged in this session.

VII. Relevance to research questions

Do spreadsheets as a Computer Assisted Instruction (CAI) application improve learning and teaching in problem solving activities?	Pupils today were observing the relations between the numbers as they were filling in the table to solve the problem (by increasing the number of the small cups). **Instead of filling in the table with numbers in random order!
In what ways do spreadsheets as a Computer Assisted Instruction application influence pupils' achievement in solving problems?	
Are there variations in the effectiveness of Spreadsheets as a Computer Assisted Instruction application among different types of pupils?	N/A

New hypotheses suggested & Implications for subsequent data collection:
Formation of Groups.

Group 1 S10 was moved to Group 3 (see notes above).	**Group 2** Spent a lot of time in formatting the Table - Finally they did not save the file.	**Group 3** Was helped by S10 (see notes above).
Group 4 Finished first and make use of the technique of copying the formulas.	**Group 5** Worked very hard and systematically, they have written down the formulas correctly (with my help) formatted the table but did not ended to a solution.	

List of Attachments:
A print out of the work of Group 5.

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VIII. APPENDIX F: Pólya's Heuristics

George Pólya' s Heuristics

First.
You have to *understand* the problem.

UNDERSTANDING THE PROBLEM

What is the unknown? What are the data? What is the condition?

Is it possible to satisfy the condition? Is the condition sufficient to determine the unknown? Or is it insufficient? Or contradictory?

Draw a figure. Introduce suitable notation.

Separate the various parts of the condition. Can you write them down?

Second.
Find the connection between the data and the unknown.
You may be obliged to consider auxiliary problems if an immediate connection cannot be found.
You should obtain eventually a *plan* of the solution.

DEVISING A PLAN

Have you seen it before? Or have you seen the same problem in a slightly different form?

Do you *know a related problem*? Do you know a theorem that could be useful?

Look at the unknown! And try to think of a familiar problem having the same or similar unknown.

Here is a problem related to yours and solved before. Could you use it? Could you use its results? Could you use its method? Should you introduce some auxiliary element in order to make its use possible?

Could you restate the problem? Could you restate it still differently? Go back to the definitions.

If you cannot solve the proposed problem try to solve first some related problem. Could you imagine a more accessible related problem? A more general problem? A more special problem? An analogous problem? Could you solve a part of the problem? Keep only apart of the condition, drop the other part; how far is the unknown is the unknown then determined. And how can it vary? Could you derive something useful from the data? Could you think of other data appropriate to determine the unknown? Could you change the unknown or the data, or both if necessary, so that the new unknown and the new data are nearer to each other?

Did you use all the data? Did you use the whole condition? Have you taken into account all essential notions involved in the problem?

Third.
Carry out the plan.

CARRYING OUT THE PLAN

Carrying out the plan of the solution, *check each step.* Can you see clearly that the step is correct? Can you prove that it is correct?

Fourth.
Examine the solution obtained.

LOOKING BACK

Can you *check the result*? Can you *check* the argument?

Can you derive the result differently? Can you see it at a glance?

Can you use the result, or the method, for some other problem?

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