A CLASSROOM-BASED INVESTIGATION INTO THE POTENTIAL OF THE COMPUTER SPREADSHEET AS A LEARNING TOOL WITHIN THE SECONDARY SCHOOL MATHEMATICS CURRICULUM.

THESIS

Submitted in partial fulfilment of the requirements for the Degree of

MASTER OF EDUCATION
(COMPUTERS IN EDUCATION)

of Rhodes University

by

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October 1991

ABSTRACT

The influence of modern technology on education is becoming more noticeable and has implications for the curriculum and the teaching methods of mathematics.

The microcomputer can be used effectively as a powerful teaching and learning aid within the mathematics classroom. This study considers the role of the computer as an aid to teachers and pupils in the teaching and learning of mathematics and shows it as having great potential. At present relatively few schools in South Africa are using the computer as a teaching aid in the mathematics classroom. The researcher proposes that some reasons are a shortage of suitable programs, the fact that few teachers have adequate skills in educative uses of the computer and most teachers are not skilled in programming techniques. Based on this assessment of the problem, spreadsheet programs related to some mathematics lessons, together with teaching notes and pupils' material have been developed.

Besides describing the potential of the computer in mathematics, this study outlines the development of three spreadsheet packages and suitable teaching methodologies used for each package, and assesses an action research investigation undertaken by the researcher, teachers and pupils when using these spreadsheet packages in six classes. The findings of the investigation are most encouraging.

The overall conclusion is that computer spreadsheet packages can assist the teacher in making the learning of mathematics more effective, more interesting and more enjoyable.

ACKNOWLEDGEMENTS

I am indebted to the following and to them I would like to express my sincere thanks.

* My husband, Robert and children Debra-Lynn, Richard and Marc for their encouragement, love and support.

* My supervisor, Terry Marsh for his time, advice, constructive criticism and encouragement through the various stages of development.

* Lucia Lotter, Judy Sheard and the Principals and pupils of Kaffrarian High School and Dale College for their support and co-operation at all times.

* The Cape Education Department for their granting of leave.

* Theo Swart and his family, who assisted in the laser reproduction of the thesis.

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CHAPTER 1

ORIENTATION AND STATEMENT OF THE PROBLEM

1.1 INTRODUCTION

The possible applications of computers in education are expanding rapidly - from routine drill to highly creative usage. This technological advancement places pressure on the teachers to find new ways of preparing the pupils for a future world where continuous change will demand flexibility in all spheres.

Merrill et al. (1986:172) point out that one of the major differences between humans and the lower form of animals is in the use of tools. Many tools have been invented to improve and extend our physical capabilities, for example, shovels to dig and washing machines to wash our clothes. Tools, such as pencils, pens, blackboards and chalk, have also been developed to facilitate teaching and learning. With the advent of the computer, we now have a tool to extend our mental capabilities. Yet the researcher believes that very few educational institutions in South Africa have incorporated software tools into the teaching or learning process, whereas industry is frequently relying on these tools to enhance the quality of its products and to reduce production costs.

A comprehensive national survey undertaken by Becker in America, in 1983 (Harper 1987:36), showed the increasing availability of computers within education. Still, according to Harper (1987:52), there are not enough computers for

pupils to spend much time using them. Nonetheless, the rapid growth of computers and the dramatic rise in the number of pupils with access to a computer could have a marked effect on the mathematics curriculum and on the teaching and learning of mathematics in the future.

Papert (1987:4) argues that

> *We should be talking about the opportunity offered us, by this computer presence, to rethink what learning is about, to rethink education.*

The implication is that the computer may open new areas of mathematics to be taught or it may coerce teachers to develop a different style and approach to complement the instructional methods already in use in some parts of the traditional curriculum.

1.2 THE NATURE OF THE PROBLEM

The computer has great educational potential (see Chapter 3) that could be used within the subject classrooms in the schools. However, it is not the intention of this research to make the reader think that all mathematics teaching and learning must be done on the computer. This provides a very narrow view as it fails to appreciate other available resources within education.

In an attempt to locate South African literature on computers and mathematics, the researcher is struck by the fact that very little is available. A teacher who wishes to learn more about the availability, use and management of the computer within the mathematics classroom has to resort to overseas literature.

A literature survey of some writers (Kelly 1984, Ball 1986 and Chen & Paisley 1985) and research done by Cox, Rhodes and Hall (1989) indicated that in some schools in the U.K. and America, computers were often locked away. Other schools used them for computer studies to teach programming to selected pupils, whilst the majority used them for computer literacy only. More specifically, Becker's (1985:91) survey in America recorded that in the Secondary schools, 85% of computer use was for general computer literacy, 76% for programming, while only 22% was for demonstrations, labs and simulations. The position has surely changed since this survey. Nevertheless, it still registers limited use of the computer within the subject classrooms.

On the other hand,

> *[there is a] growing collection of valuable examples which highlight how a micro can be used <u>in</u> the classroom to stimulate, encourage and assist pupils in their mathematical venture.*
>
> *(Bufton 1986:14 -researcher's emphasis)*

Likewise, research by Fletcher in 1983 in Britain (Bufton 1986:12) described the use and the influence of the computer in the methodology of mathematics within some classes, resulting in pupil enthusiasm and motivation that was lacking before. So, it could be argued that some teachers have recognized that the computer may significantly contribute to mathematics education by making available alternate teaching and learning strategies.

Carl (1989:471) states that the National Council of

> *... the use of calculators and computers and the application of statistical methods will continue to expand. Creative problem solving, precise reasoning, and effective communication will grow in importance.*

Furthermore, the NCSM advised that the computer should be used as a teaching aid in the classroom.

> *The use of computers should be incorporated throughout the K-12 maths curriculum. ... Computers should move away from drill and practice [only] on isolated low-level skills and toward meaningful involvement by students in problem solving and concept development.*
> *(Carl 1989: 473)*

The Working Document (Draft 2) for the new mathematics syllabus in South Africa clearly supports this view, when it suggests as one of its aims that it should develop in pupils:

> *The ability to use a range of mathematical methods and technological aids sensibly and appropriately.*
> *(DEC 1989:2.2.7)*

Also a proposed teaching method, for the Statistics component in the new Junior Secondary Course Syllabus for Mathematics Ordinary Grade implemented in South Africa in 1991, is that, if a computer and the necessry software are available

> *... pupils could enter and access information in a simple database (CED 7.9.1) and*
> *Data may be handled using spreadsheets. (CED 7.9.5(a))*

From the above extraction, it seems that, where possible, the computer should form part of the resources available to the mathematics teacher. Opportunities should be created to use the computer as a computational and instructional aid in relevant sections of the mathematics curriculum so that it could improve, maintain and enhance learning experiences, skills and the understanding of mathematics.

However, lack of time, limited computer access, enthusiasm and the possible organisational workload of the teacher often

hinder genuine integration of the computer within the classroom. Still, the real potential of the computer will only start to emerge when the teachers come to see and use it as an educational tool.

The spreadsheet offers a possible method of using the computer as a tool to enhance teaching and learning within the classroom. Spreadsheets are arrays of rows and columns that can hold data. Algorithms and mathematical problems that can be set up in a table format can be implemented on a spreadsheet so that it allows teachers and pupils to change initial values, step sizes and other parameters and instantly see the results of the changes.

Laridon (1986:3) points out that research and development in the use of spreadsheets in teaching mathematics is needed. The researcher suggests that lessons using the spreadsheet that are directly related to the content of the mathematics syllabus should be developed and that if possible, documentation accompanying these lessons should include teachers' notes and/or pupils' worksheets and instructions. The intention is that these packages will be a source of mathematical ideas and allow for flexibility of approach for the teacher within the class.

Therefore although there have been considerable developments, particularly in America and Britain, regarding the use of the computer within the mathematics classroom, much work still has to be done. It would appear that a detailed scrutiny of the potential of the computer for mathematics and of ways to implement this new tool within the South African mathematics curriculum in the Secondary School classroom is necessary.

1.3 OUTLINE OF THE INVESTIGATION

1.3.1 AIMS OF THE INVESTIGATION

In light of the above, the prime purpose of this research is to examine the potential of the computer as a learning tool and how it can be considered as an aid to teachers and pupils in the learning and teaching of mathematics.

Secondly, the purpose is to ensure that this research does not remain an academic exercise. So the final section will consider the classroom management of the computer and the feasibility of using spreadsheets as a learning and teaching aid for some sections of the mathematics curriculum.

1.3.2 RANGE OF THE INVESTIGATION

To achieve these aims, a simplified discussion of some learning models will be presented to provide an adequate theoretical basis to illustrate the contrasting roles of the computer, its potential in learning and the resultant implications for mathematics teaching. However it is not possible to evaluate the potential of the computer or to make any meaningful suggestions for the improvement of mathematics teaching in some areas without first considering the aims, possible learning objectives and the nature of mathematics teaching in the classroom. Only after this can thought be given to the role of the computer to examine what contribution it can make, how the computer can be managed within a lesson, how these computer activities might link to a teaching model for mathematics and then specifically how the spreadsheet can fit in, to attain these educational aims.

Spreadsheet packages, for some sections of the mathematics syllabus, will be developed so that teachers could use this dynamic new teaching aid. A small-scale action research case study will then be conducted, using these packages, to examine the effect of the use of the computer as an aid within lessons. A questionnaire administered to the pupils after each lesson and a non-participant observer, in this case another mathematics teacher, will provide feedback on the success of this interactive approach and method in achieving the objectives of the lesson.

These findings will be used to reflect on the action of applying the packages within the lessons and, in terms of the action research methodology, adaptations made to improve them. The results of this research will be described, assessed and discussed in the final chapter. Finally some recommendations for future planning of the use of computers within the mathematics classroom will be considered.

1.3.3 Conclusion

This research is an attempt to describe and test the packages in practice, so that the researcher might observe the effect that this type of teaching strategy has on mathematics learning and then assess its value. The acquired understanding of the pupils' reaction to this innovation and the insight gained regarding the computer as an aid, should make it possible for teachers to reflect, improve, change or reject the teaching methods and approaches in order to make learning more meaningful for the pupil.

CHAPTER 2

SOME GENERAL CONSIDERATIONS AND IMPLICATIONS FOR THE TEACHING AND LEARNING OF MATHEMATICS

2.1 NATURE OF MATHEMATICS

What is mathematics?

Literature (Cockcroft 1982, Orton 1987, Murray 1988) provides a plethora of view points between two extremes. These range from the practical and formalistic view of rules, theorems, certain skills, etc., to the aesthetic and abstract view of logic, intuition, etc. On the one hand it is mathematics for practical applications and on the other hand it is mathematics for the sake of knowledge.

This implies that mathematics is a discipline that includes both the product and the process. So it can be seen as a body of knowledge and a creative activity in which the pupils participate. If one accepts this statement then an awareness and consideration of the following could be important for the teaching of mathematics.

2.1.1 Mathematics is a language that has its own precise rules, notations, theorems and structure that the pupils must comprehend before using it in a meaningful way. It is formal, concise and consistent when it communicates ideas, persuades or sets out a logical argument. Mathematical ideas can be presented by speaking, writing, in pictures, graphs and models. So the implication for teaching is that

> *since language is an essential component in the formation, expression and communication of mathematical ideas, all pupils need to be provided with opportunities to verbalise their learning experiences and observations. (MASA 1988:6)*

However this language does not always relate to the world the pupils live in so that the demands made could be too much for them. One problem is that some words used in a rigid mathematical context have a less restrictive interpretation of meaning in ordinary language usage. Another problem is that mathematics may use common words with meanings that differ from those in the ordinary language, for example, 'prime'. Also the reading action (not always from left to right and a mixture of symbols, words, icons) of mathematics differs from the normal reading action of words. So, according to Hultzer (1982:55)

> *We have the child having to cope with the problem of having to accept the discipline of unique meanings, which is strange to him, as well as having to apply different meanings to some familiar words.*

When looking at the new evolving position of education in South Africa, most of the pupils learn mathematics through the medium of a spoken and written language that is not their mother tongue. According to Orton (1987:137) the language communicated to these pupils is translated into another by the pupil, to allow for thinking, and then translated back to converse with the teacher. Misunderstanding can therefore result at any point in this two-way communication.

This is then further compounded with the use of the computer as a learning aid. Stoker and Robertson

(1989:374) point out that as most of the software originates from overseas, the vocabulary and concepts used may lack direct cultural relevance particularly for the black pupil in South Africa. This is a real problem that should not be dismissed easily.

2.1.2 Mathematics is a dynamic tool in a technological changing world. It has a wide range of applications in other disciplines like geography, science and economics. Also entrance into a variety of careers requires a certain standard of mathematical knowledge. The structure of mathematics is such that it is a study in patterns and relationships. It explores and describes space and quantity in the physical world which allows one to hypothesise and draw conclusions. It can provide both graphic and formula models of problems under consideration. It also develops visual skills, reasoning, problem solving and mathematical thinking and contributes to the development of spatial awareness and logical thinking.

Still, the pupils generally find it difficult to relate problem solving within the classroom to the same problem in the real world. One reason is that the methodology in mathematics teaching is often reduced to mechanical manipulation and memorisation of algebraic symbols without enough attention given to understanding, the development of processes like pattern recognition, generalisations, etc. Another is that problems frequently lack authenticity in an applied context. Problems often consist of situations

having no practical application so that the mathematics taught is then seen as useless. Also Presmeg (1988:41) warns that

> *... mathematics usually taught at school was developed in and for a particular culture ... Those pupils from a different cultural background may not have access to these patterns and assumptions ...*

2.2 AIMS OF MATHEMATICS

The aims in the new mathematics syllabus for South Africa, contained in the Working Document (Draft 2), show an awareness of the variety of view points put forward in the above section.

Aims such as the following are stated (DEC 1989:3)

> * *the ability to use a variety of mathematical processes, e.g. comparing, classifying, analysing ... in learning and doing mathematics*
>
> * *the ability to understand, interpret, read, speak and write mathematical language*
>
> * *[to develop in pupils] the mathematical skills necessary for future employment and careers*
>
> * *the ability to apply their knowledge of mathematical concepts, methods and processes ... to solve relevant problems*
>   - *set in a mathematical situation*
>   - *by recognising real-world situations, ... formulating the mathematical model, selecting the mathematical solution and interpreting the result back in the real-world situation*

So the implication for teaching is that mathematics should be taught according to the nature and structure of the subject and the demands it sets.

> *[The] teaching approach should include activity based learning, discussion, problem solving, open-ended investigations.* *(Laridon 1990:19)*

However the nature and structure of mathematics is such that it places high demands on the teachers and the learning of the subject. The teachers and pupils have to acquire and master a diversity of skills. Also the use of uniform methodologies within the class is almost impossible because of the differences in the background knowledge, interests, learning tempo, etc., of the pupils. This implies that methods should be found to satisfy the demands of mathematics and simultaneously, enough opportunities should be created within the classroom for the variety of learning styles of the individual pupils. (Slabbert 1990:54)

Teaching, together with any resource used, should take into account the learning activities of the pupils to attain the above aims. Since personally held theories about learning usually determine the teacher's use of a particular methodology, a teacher's decision should be based on the best learning theory available for a specific topic. For this reason, teaching should occur within the framework of a learning model to provide a theoretical basis to reflect on how the pupils learn and construct knowledge. So before considering the educational potential and utilisation of the computer, attention should be given to the relationships that could be established between the pupils and the learning content to promote effective learning.

2.3 MODELS OF LEARNING IN THE LEARNING PROCESSES

There are many models of learning and learning environments - on how people learn and what the capabilities of the pupils are at various ages. For this research, an outline of some

of the models will be presented in a broad simplified form in order to illustrate the contrast between some of these general learning theories. It is also the difference of these approaches that has led to the heterogeneous use of the computer. The brief descriptions that follow, formed part of the discussions held within the M.Ed. classes at Rhodes University during April 1990.

2.3.1 Behaviourism

The behaviouristic approach, with Skinner probably the best known exponent, assigns a passive role to the pupil in the learning process. This theory sees learning as conditioning. It states the learning objectives in terms of what the pupil can attain at the end of the learning process. The content is presented in short steps and tasks, in a logical sequence, with regular rewards for specific responses to stimuli. Absorption of these new facts then occurs in an arbitrary way for verbatim recall, suggesting that rote learning takes place as these facts are not linked to any previous knowledge. Psychologists who support this theory place no emphasis on the process of learning. The product and not the process is important.

Blease (1986:24) intimates that this learning theory is only suitable for simple examples of learning, as it leaves many unanswered questions about the pupils 'intuitive' perception of certain situations as a premise for responding to stimulations. Unfortunately, the ultimate aim for many mathematics teachers, seems to be the teaching and practice of mechanical manipulations of numbers, algebraic symbols, etc., to arrive at the 'correct answer'.

2.3.2 Cognitive theory

Within the cognitive approach, Piaget and Bruner the main exponents, the pupils play a more active part in their learning. The pupils become actively involved and take responsibility in the learning process. Although the teacher has to organise the pupil's learning environment so that learning can take place, it is still the pupil's activity that determines the learning outcome. The pupils use language and seek meaning through a variety of experiences, which in turn leads to understanding and finally to the ability to use the newly acquired knowledge. Even without understanding the pupil can describe a concept symbolically, but will not be able to use it meaningfully until reaching a stage of development allowing for the understanding of the new concept.

Social interaction plays an important role in developing thinking skills. So the pupils should have an opportunity to interact with the teacher and their peers. This allows the pupils not only to receive feedback on their performance, but also enables them to watch how, for example, others solve a problem.

The implication for mathematics teaching and for the selection of software, is that instruction should be at a level concomitant with the stage of development of the pupil. The pupil should be given an opportunity to apply what has been learned in a previous situation to the new situation. However there is always the danger that the teacher or computer program may be presenting the materials in an

abstract way whilst the majority of pupils are still thinking at the concrete level. Also all the pupils are not necessarily at the same developmental levels within any secondary class. Consequently, it is not always possible to present advanced learning material to all pupils expecting eventual assimilation into the cognitive structure.

Nonetheless Orton (1987:79) cautions mathematics teachers to keep an open mind on the issues of these readiness stages, as it could be detrimental to the cognitive development of the pupils if it is assumed too easily that they are not yet ready for a new concept.

2.3.3 Constructivism

The third model is the constructivist perspective, influenced by the ideas of educators like van Hiele and Freudenthal. This model stresses the fact that the pupils actively receive knowledge from the environment. The pupils construct and organise their new concepts. They are not just accepted or memorised. Although the pupils can build up concepts through unguided experience, these concepts will probably be far less complex than those formed under the teacher's guidance. So the teacher plays a vital role by helping the pupils to assimilate more complex concepts

> *... because knowledge cannot be transferred ready-made. To support the child to construct his own knowledge, discussion, communication, reflection and negotiation are essential components ...* *(Olivier 1989:12)*

Very broadly then,

* pupils enter the learning situation with specific pre-knowledge that differs from pupil to pupil;

* each pupil then tries to interpret their encounter with this new experience and knowledge;

* in the attempt to interpret this, the pupils use their existing knowledge to reconstruct and organise the new knowledge into an appropriate unit of interrelated ideas. The pupils therefore build up meaning for themselves by attaching unique interpretations to these new concepts.

Constructivism is clearly inherent in the following principle in the new mathematics syllabus for South Africa to be implemented in 1991.

> *The pupil learning mathematics is conceptualised as an active mathematical thinker who tries to construct meaning of what he is doing on the basis of personal experience and who is developing his way of thinking as his experience broadens, always building on the knowledge which he has already constructed. (DEC 1989:1)*

This school of thought holds that the mathematics teacher should be conscious of the relationship that exists between the pupils' current scheme of concepts and their possible interpretation of new learning experiences. So successful communication of any new concepts should be accompanied by an adequate body of meanings. Nevertheless, although explicit instruction affects the pupils' learning, it still does not determine what they learn.

A simple comparison of the latter two theories is that in Piaget's model some pupils will not be able to acquire certain concepts because of never reaching an abstract level of formal thinking, whilst the constructivists acknowledge that all pupils could learn a piece of material if the teacher structures the learning experiences properly. This is a far more optimistic and positive view that could present

a rewarding challenge to teachers when they experiment with different instructional methods on specific topics.

2.4 SYNOPSIS

Knowledge of the general learning theories can help educators have some idea of the thought processes that are at work when mathematics is learned. However, Orton (1987:3) warns that it would be foolish to tie, for example, rote learning too closely to the behaviourist model and imply that it lacks a place in the other models. Pupils do need to develop understanding by building up meaning for themselves, but there is still a definite need for practice in mathematics.

Mathematics educators should aim at developing different types of capabilities in a pupil. According to the NCSM,

> *... students must develop a thorough understanding of mathematical concepts and principles; they must reason clearly and communicate effectively; they must recognise mathematical applications in the world around them; and they must approach mathematical problems with confidence. (Carl 1989:471)*

So mathematical learning is not just a simplistic process as assumed by instruction based on the behaviouristic paradigm. If the emphasis is only on rote-learning then it becomes difficult to promote higher thinking levels. For the teaching and learning of mathematics to be effective all the above theories should be considered. In particular, teaching and learning strategies should possibly contain a blending of these theories when using the computer as a teaching and learning tool.

2.5 CONCLUSION

Since it is assumed that mathematics teaching should be in accord with the nature of the subject and since the nature of the subject has implications for the aims of the subject, it seemed appropriate to pay attention to the nature and aims of mathematics in this chapter. The teaching and learning of mathematics then occurs within a framework of learning theories, as a basis to consolidate, elucidate and explain concepts. With these models in mind, the next chapter examines some available computer environments for mathematics.

CHAPTER 3

POTENTIAL OF THE COMPUTER FOR MATHEMATICS

3.1 THE CONTRASTING ROLES AND POTENTIAL OF THE COMPUTER WITHIN THE LEARNING MODELS

> *The major advantage of the microcomputer is not that it can think for one but that it can make one think, so that its potential for promoting the development of children's thought processes is enormous.*
> *(Kelly 1984:XIV)*

The constrasting approaches of the learning models accounted for in the previous chapter have led to different exploitations of the computer. As a result, there have been many attempts to classify the role of the computer in education. Blease (1986:37) applied Chandler's system of the concept of 'locus of control' into which the educational programs fit, depending upon the role played by the pupil. This role extends from the pupil being computer-guided to the computer being pupil-guided. On the other hand Adams (1988:1) utilised Taylor's model of Tutor, Tool and Tutee for the discussion of some computing issues. As a tutor the computer takes on the role of a teacher, as a tool the role of an assistant and as a tutee the role of a learner.

However

> *each program's effectiveness will depend upon the specific purpose for which it is used as well as on its potential to develop certain capabilities in learners.*
> *(Flouris 1989:17)*

Within this framework, only the contrasting approaches of Adams's scheme will be expanded upon by defining some

specific categories for each of these classifications and then briefly identifying where potential applications might be placed.

3.1.1 Tutor

Drill-and-Practice and Tutorial programs

Advanced teaching machines were first introduced in the 1960's and mainly used with drill-and-practice type programs, based on the behaviouristic approach. However, Flouris (1989:15) intimated that most computer programs based on the behaviouristic model were limited in their potential to develop critical-mindedness, decision-making skills or other cognitive skills.

Possibly the major weakness of tutorials and drill-and-practice programs is that the content and sequence of the presentation is rigid, fixed and supplied in small learning tasks at a time. As Blease (1986:22) pointed out,

> *in a sense their limitations correspond to the limitations of the psychological theory of learning upon which they are based, namely those of behaviourism.*

Drill-and-practice type programs are usually only used after the teaching or development of new subject matter. The lesson objectives are the inculcation, consolidation and mastery reinforcement of facts, concepts, relationships, processes and procedures in small steps. The computer provides material for pupil interaction and response, tests this response to decide the next stimulus and then permits sequential progress to a pre-determined level of proficiency after satisfactory completion.

This approach makes some assumptions about the nature of the subject matter and knowledge. It depicts an atomistic concept of knowledge, reduces some curriculum areas to a sequential structure only and also assumes that all pupils conform to a behaviouristic learning model. (Baker 1984:113).

Still the computer could be seen as very valuable as it has 'patience', allows the pupils to proceed at their own pace, provides immediate feedback and positive reinforcement and 'never loses its temper'. According to Olivier (1987:57), research has shown firstly, that feedback is the most important variable in the mastering of skills and in the forming of new concepts, and secondly that feedback must be immediate for the best results, else the pupil will possibly reinforce incorrect concepts.

Tutorial type programs on the other hand, are a little more sophisticated. The objectives are to introduce new subject matter and to test retention with the emphasis on the pupils' perceptive mastery of new facts and concepts. These programs force the pupils to achieve these objectives by providing them with a computer-guided sequence for the learning of new concepts. Continuous remediation is usually provided and interest is maintained through, for instance, graphics and animations. Teaching can take place at any time or venue and can be interrupted and resumed at will. However a severe limitation of these programs according to Marsh (1989:21), is that there is no individualisation as the presentation of each unit is in precisely the same way to every pupil. Also there is a loss of dynamic interaction between the teacher and the pupil.

In addition, Retief (1989:150) warns, amongst others, that some problems associated with the implementation of CAI are the following:

> * *The language medium. In the South African educational context the language medium has been a definite impediment. Usually when an American or English program is found to be acceptable, no Afrikaans [or African language] equivalent is available.*
>
> * *Accuracy and applicability of subject matter. Factual errors occur, and much overseas CAI lesson material does not fit South African requirements.*
>
> * *Documentation tends to be inadequate or altogether lacking.*

Well-developed tutorial programs can nevertheless be tailored to meet varying ability levels and specific skill deficiencies of pupils. This is important as teachers could use these programs for reinforcement or remediation, depending on the pupil. Still it cannot be expected that a tutorial program can teach pupils a new concept effectively without a good teacher introduction and classroom practice to go with it.

From a cognitive point of view, pupils could only use these programs if they are operating at the correct stage of development for the program, else the drill would become pure rote learning and fail to promote real understanding.

Murray (1988:5-6) states that from a constructivist point of view exposing the pupils to drill-and-practice type exercises can only take place when the pupils have already constructed the conceptual base and mastered the concepts that will make the facts meaningful. Premature exposure of facts could encourage rote learning and therefore the consolidation of incorrect strategies. Nevertheless drill-and-practice could

supply valuable experience to pupils who have formed a strong conceptual base and therefore need to attain fluency.

Still the practicing of skills and the regular use of drill programs does not bring about any real change to traditional instructional techniques used in the classroom. As only one pupil at a time can use the computer for drill-and-practice it becomes a very expensive teaching machine. The same argument applies to the use of the computer as a tutorial delivery medium as only one or two pupils usually use the computer at a time. If the use of the computer is limited to drill-and-practice or tutorial only, it would be a waste of an exciting and expensive resource that is available.

On the other hand, drill is important for complete mathematical competency. As Murray (1988:5-6) maintains, if the pupils cannot manipulate the relevant information within a reasonable amount of time or execute an algorithm with speed and accuracy, then their understanding of the concepts is of little practical use. The drill-and-practice programs could therefore play an important role in bringing the learner to a level of fluency to perform more readily at higher levels. They could be used successfully as an aid to the teacher and pupil whenever it is appropriate.

Simulation programs and games

Simulation programs provide more of a resource or aid to the teacher or pupil, than just a drill-and-practice type teaching machine. It is in this mode that exponents of the cognitive approach to learning would see the computer put to best use.

Simulations usually prove to be exciting and provide enjoyable learning experiences for the pupil. The pupils learn not only facts, ideas and theories, but the 'how', 'why' and 'what if' of these facts. They are actively involved, as they can change inputs, try out ideas, etc. The pupils learn by doing and thinking about what they are doing so that unconsciously they master the strategy built into the simulated program. Simulations are therefore freer than the rigid techniques of the behaviourists. Simulations model decision-making in the real world with the pupils freely making choices and decisions.

The pupils, when using simulations, can experience phenomena that would otherwise be too expensive, very dangerous, time-consuming or impossible to undertake in their actual form, for example, the effects of a nuclear reaction on the immediate surroundings. Actual laboratory experiments, ecological and field trips can also be translated into simulations. This saves costs, time, energy, and organisation as the recurrent costs of these simulations are negligible and the preparation of a computer simulation lesson requires far less work than the setting up of, and clearing away after, a laboratory lesson. Also the data available from simulations is readily available for interpretation, so pupils can carry out many 'experiments' in a short time to permit deductions of underlying principles. Pupils acquire an understanding of the simulation model by observing and analysing the results. Simulations therefore do not only function in the descriptive mode, but could also successfully be used to make predictions, for example, how fast an aids epidemic will spread throughout a community.

However a major weakness with simulation programs is that pupils are not held accountable or do not learn to take responsibility for their actions, for example, an incorrect decision causing an aircrash within a simulation does not have the same impact as a 'real life' plane crash. Also if simulations replace all field trips and laboratory experiments within the school and classroom, the pupils will be sold short on practical involvement, experimental and technical skills.

Simulations encourage problem-solving, discovery learning and provide a framework for developing logical thinking patterns. As these programs help to develop thought processes they lead one away from the product (where the focus is on skill and facts) to a process approach. Problem solving and investigations like this foster cooperation and communication between the pupils. However, the teachers must monitor this communication, as it could just develop into a lively conversation with, for example, no meaningful mathematics learning taking place. Also this social interaction might create emotional stress and worry for pupils that find interaction difficult, so teachers should prepare pupils for this type of learning environment.

Still it must be remembered that simulations are not designed to stand alone. Without proper lesson preparation the pupils will not receive the expected benefit in that they will find it difficult to link the new knowledge into their relevant existing concepts. Likewise after the use of a simulation the teacher should help the pupils to integrate and transfer their new concepts to the real situations.

This simulated mode could prove effective and popular for mathematics teaching in that it allows pupils to observe, study, analyse and review the results of any actions taken. In mathematics the computer can, for example, simulate the probable outcomes of many hundred tosses of a coin or dice.

However Blease (1986:45) argues that simulations are based on real-life situations that are fairly rigid. The pupil can therefore only experiment with changes to those prescribed conditions permitted for a particular simulation. This implies that the teacher would have to judge to what extent a simulation has been simplified before selecting a simulation that fits, so that the expected learning outcomes are consistent with the objectives of the lesson.

Games on the other hand, model only certain elements of reality. They often have conceptual skills embedded in them that pupils must master in order to be successful. They are challenging and bring motivation, interest and curiosity to the learning situation. Also the teachers can always direct learning through games without restricting joy, excitement and creativity. Kelly (1984:9) however warns that,

> *... the motivation ... inherent in the microcomputer may not be the most appropriate kind of motivation and there may be dangers in accepting it at face value.*

Adventure games provide opportunities to use logic, reasoning and organisational skills to solve problems. Such games normally take a long time to solve with very little guidance given, so that it can become frustrating to the pupils if they cannot continue. If teachers use these type of games in the classroom situation they must therefore carefully

prepare the pupils before and after the lesson. The pupils must not be allowed to just play without the experience leading to some positive learning outcome.

Retief (1989:152) remarks that

> *participation in a game requires certain skills, abilities and/or techniques on the part of the pupil in order to find the best or winning solution. [This implies that] the teacher exploits this requirement by designing games which incorporate educational skills, abilities and techniques.*

The high motivational factors involved in games suggest that gaming attributes and educational objectives could profitably be integrated into drill-and-practice, tutorials and simulation applications.

The use of simulations and games is far more cost effective than for drill-and-practice as larger groups of pupils at a time can use one computer. With worksheets to guide them and well-designed pre- and post-activities the computer can be used without much teacher intervention.

Simulations and games are exciting applications for mathematics teaching. As they allow pupils active interaction and manipulation of phenomena they should perhaps form an integral part of the instructional activities in the classroom. However, the teacher should always provide the pupils with the necessary information and underlying principles enabling them to obtain the maximum benefit from participating in a particular game or simulation. (Merrill et al 1986:74)

3.1.2 Tool

> *The tool model is one in which the computer has some practical utility in terms of saving time and preserving intellectual energy by transferring the routine tasks to the computer, or enhancing human creative skills.*
> *(Adams 1988:3)*

Tool applications are those that help the pupils do something better, faster, more accurately, more economically or with less frustration than by conventional means. The computational mechanical workload is reduced so that real learning can take place without the burden of first having to process laborious calculations or other data that usually take a fair amount of time and that is prone to many mathematical errors. So instead of using the computer to deliver traditional instructional activities, it can be used as a tool for assisting pupils in developing understanding and learning skills.

When using the computer as a tool, the pupils manage the machine, store, manipulate and investigate data. By evaluating the outcome of the chosen variables or by changing the variables the pupils get immediate feedback, begin to understand new concepts and get the feel for generalisations. This mode thus allows the pupils to explore a variety of situations, test out ideas and develop new concepts. When engaging in, for example, information retrieval pupils get a feel for information handling and in so doing acquire skills for coping with the information explosion of this decade.

The computer as an instructional tool is similar to a calculator, typewriter, etc., as it requires active involvement on the part of the pupil. The pupils ask the

questions and not the computer so instead of the computer controlling the pupils, the pupils control the computer and as a result the pupils acquire a feeling of domination over the computer. Use of this new technology therefore possibly implies new educational goals and approaches to learning.

Generic software, with the electronic spreadsheet and a graphics software program good examples, falls into the tool category. A benefit of using generic software is that it is content free, adaptable, requires no fixed methodology and can be used across the curriculum. It is also open-ended as available options and possibilities for these programs are very wide.

A specifically designed graphics program, for example, makes the teaching of all graphical representations very easy when compared to traditional methods. Although it is necessary for the pupils to actually physically draw a lot of graphs, it takes a long time. It is not so easy to manually generate many graphs within a normal lesson so that the effect of a specific component of the function could be isolated and thoroughly discussed. The nett result is that the graph itself gets absorbed in the mechanical process of sketching it so that the importance of the shape of the graph becomes lost. However when using the spreadsheet or the graphics software program as a tool, the actual sketching of the graph could be put aside for a while in order to concentrate on the function and its specific representation. Furthermore, the electronic spreadsheet seems a good environment for mathematical computational problem solving, as the pupils must exercise their mathematical knowledge when using this

tool to solve problems. Because several skills, concepts and strategies are involved, the use of the spreadsheet deepens their understanding of mathematics, so that it can become an invaluable tool in the mathematics classroom. It also fits into the constructivist mode of learning because the pupils have to analyse the problem, plan and then reconstruct these new concepts to build up meaning for themselves.

However, it would seem that very few teachers are aware of the range of computer software tools that are available or how to use the tools or how to integrate these tools in the class and as a result they have hardly ever considered using them. This researcher feels that a concerted effort should be made by the teachers to consider using the computer as one resource tool amongst many when planning a lesson, because imaginative use of the computer by the teachers as a learning tool could help to create an environment in which problem solving strategies of pupils can flourish.

3.1.3 Tutee

> *In the tutee mode the computer creates a rich and stimulating environment where the students are free to explore and learn by teaching or programming the machine.* *(Chan 1989:274)*

In this role the pupils become teachers and actively communicate to the computer the different sequences of a software program. Programming a computer is intellectually stimulating and challenging and promotes logic, analysing, reasoning, ordering, sequencing and problem solving.

However before pupils can program the computer they have to learn a computer language and develop an understanding of the

inherent commands of this language. Furthermore before they can teach the computer to perform a new task, they have to understand and be able to solve the mathematical problem involved. This requires careful analysis and a clear grasp of the problem. Therefore teaching the computer allows the pupils to gain insights into their own thinking which in turn aids the development of logical and critical thinking skills and intuitive learning that is inherent in the learning process.

Still, Fritz (1985:707) issues a strong warning, in that

> *[the] problem-solving component, which is so important to everyone, tends to play second fiddle to language syntax.*

Many programming languages exist, each with its own design, strengths and weaknesses. As a beginner language for pupils, the turtle graphics of LOGO is possibly the most popular for education. It is a tool that encourages exploration and allows the pupils to identify, investigate and solve problems. Social interaction is advantageous in this type of environment as the sharing of ideas and questions with each other is a fundamental part of learning LOGO.

As mentioned before, mathematics is a language (refer to Chapter 2, Section 2.1.1) and the pupils must be given the opportunity to 'speak' it as often as possible.

> *Concept formation is considerably aided by opportunities to verbalise one's ideas. Many computer programs can provide this if the teacher encourages the pupil to work together in small groups, discussing possible strategies before putting them to the test. (Blease 1986:27)*

Programming is therefore probably the most powerful mode of computer usage for mathematics education. Not only does it

encourage social interaction, it also allows pupils to acquire a better understanding and appreciation of the algorithms used in mathematics, if given the opportunity to engage in programming activities such as tracing, debugging and the modification of existing programs. Still these experiences should focus on how programming ideas can be used to learn mathematical concepts, not on developing the pupil's personal programming skills.

Programming a computer highlights a new and positive outlook on mistakes. If a program does not work correctly then it is not because of a mistake but that the actual program has not yet reached completion and stills needs to be debugged. So within this environment the pupils do not mind making mistakes, as mistakes are not viewed as failures, but as an indication that there is more to learn about the problem. (Merrill et al 1986:77). This is of course critical for the learning of mathematics as active, real and meaningful learning is only likely to take place when pupils treat mistakes as learning experiences.

Research (Oldknow 1984 and Ball 1986) has shown that many fruitful mathematical explorations are possible with the assistance of short computer programs. These short programs can be used as aids to accompany teaching or used as problems for pupils to explore. Also a tool, like a simple graphing package, can be developed by a teacher with little programming knowledge and then used as a teaching aid within a lesson.

Still, the intention is not that all pupils should become programmers, only that basic programming skills should be taught so that the pupils could control the computer and use it to enhance mathematical, in particular algebraic, thinking. Research by Sutherland (1989:317) has shown that LOGO knowledge does enhance algebraic understanding, even although the links made between LOGO and algebra very much depend on the extent of the pupils' LOGO experience. Orton (1987:103) also refers to another study that used LOGO where

> *the most outstanding benefits were ... that the pupils had become better able to discuss and argue about mathematics, and that their problem-solving capabilities had been enhanced.*

In the researcher's opinion, programming possibly offers the ideal opportunity to learn new concepts, from the constructivists' point of view. A problem can be tried and retried by changing patterns and relationships until obtaining the required solution. The pupils naturally engage in concept construction and the organisation of the new ideas into their existing cognitive structure at the level that they can handle.

In conclusion then, the classification of the role of the computer can be viewed as if on four different levels. The spectrum of instructional activities can be illustrated (Figure 3.1) as follows.

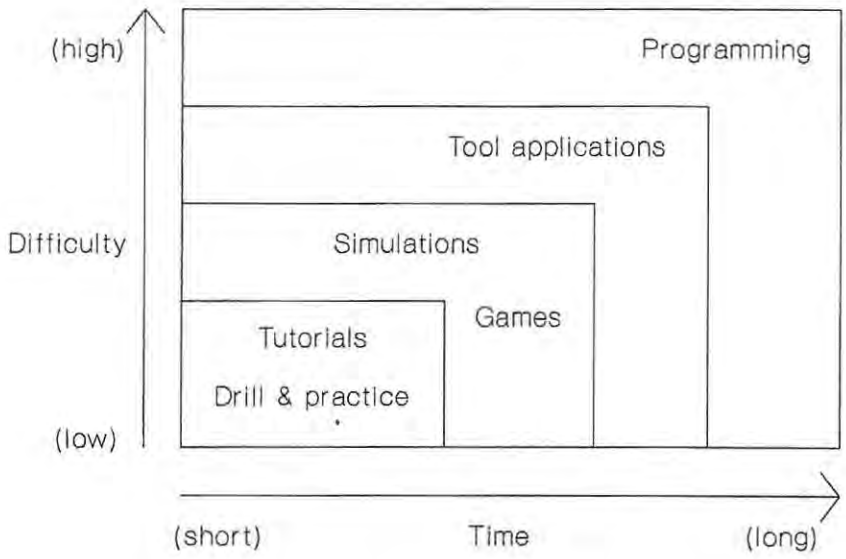

Figure 3.1 Time and difficulty spectrum of computer roles

The relationship between the degree of difficulty and the time taken to master new concepts on the computer is clearly shown in the figure. At one end is drill-and-practice where previous learning and retention is tested and at the other end is computer programming where the pupil programs the computer. This is the most time-consuming of all the different roles. Consequently the teacher must be aware of this relationship when choosing an instructional methodology or a variety of methodologies for a lesson in which the computer is used.

3.2 SUMMARY OF THE EDUCATIONAL POTENTIAL OF THE COMPUTER

Mathematics is a language that should be communicated (refer to Chapter 2, Section 2.1.1). Pupils should therefore have opportunities to explore mathematics and to talk to each other about mathematics. They should also be encouraged to ask questions within the classroom and to take risks when solving problems.

Furthermore, within the mathematics curriculum there should be an increased emphasis on problem solving, applications to everyday situations and higher order thinking. This implies that the pupils need a variety of resources and instructional modes that are suitable for the development of a wide range of skills and problem solving activities. For the pupil, the richer the learning environment the more effective the learning. However for any strategy to be effective in the classroom it must be consistent with and carefully integrated into the curriculum.

Some ideas were presented to show that the computer has the potential to enhance the teaching and learning of mathematics. The computer can, amongst others, make a worthwhile contribution by enabling

- drill exercises
- real world applications
- generalisations
- experimentations and hypothesing
- discovery learning
- simulations
- mathematical investigations

and by using it as a

- tutorial aid
- resource or teaching aid

In addition, the computer is effective in the learning situation in that it allows for social interaction and active involvement by the pupil. It acts as a tool in the real world and affords pupils the opportunity to get practice in

true problem solving. In particular, teachers can become effective catalysts for pupil-directed learning in that they are able to pose stimulating problems using the 'what if....' power of some available software.

The computer also provides one with a powerful tool for decision making, for processing information and performing calculations. According to Kelly (1984:13) it can direct one's attention to the qualitative rather than quantitative aspects of thinking and learning. It aids logical thinking and promotes the understanding of important mathematical concepts and principles.

This brief survey of the potential of the computer in education has highlighted the tremendous versatility of teaching and learning possibilities that it provides. It has become a powerful device to facilitate and promote experimentation in mathematics. For the teacher, curricular areas that are hard to teach can now be strengthened by carefully selected and integrated programs.

3.3 CONCLUDING COMMENTS ON THE POTENTIAL OF THE COMPUTER

Although the focus up until now has been on the potential and role of the computer, one must recognise that the computer is only <u>one</u> ingredient of an educational system comprised of several interrelated subsystems within the mathematics classroom. The other subsystems include the learning theories, other available resources and the role of the teacher and pupil within the class.

The emphasis of the learning theory aspect is on how the pupils learn and construct meaning for themselves. The role of the pupil/teacher focuses on the social interaction within the class, while other resources embrace all media, excluding the computer, available to the teacher. So the implication for the teacher is a required awareness of these interacting parts when planning a mathematics lesson.

The aims of mathematics together with the above subsystems can be illustrated (Figure 3.3) by the following interaction between these aspects.

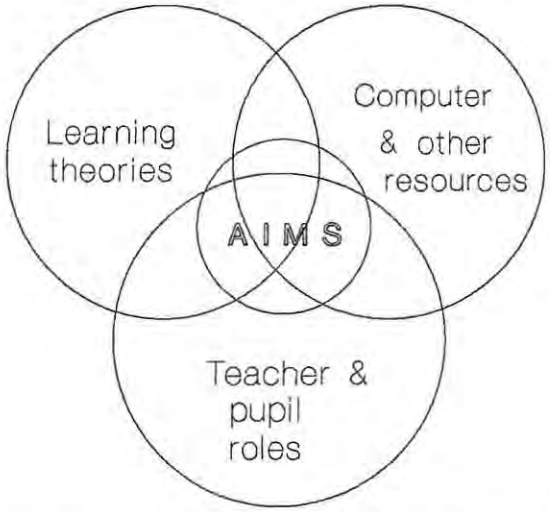

Figure 3.3 The interrelated ingredients of a mathematics lesson

The figure intends to illustrate that the ultimate statement of intent for mathematics is the accomplishment of the aims of the curriculum, which should be realized through the mathematical content and the teacher-pupil interaction. The aims form the umbrella of the system. The total system will only function very well if each of its parts is effectively interacting with one another. Therefore the teacher should

not overemphasize the importance of one subsystem at the expense of the others over a period.

Consequently if one accepts the fact that the computer should be integrated into the curriculum and become an accepted tool to be used as a teaching and learning aid, then cognisance must be taken of the previous paragraph. The computer should not be used in isolation, to the detriment of the other interrelated parts within the class.

Whatever the for or against arguments are, the computer is an available and flexible, although not necessarily affordable, tool for the mathematics teacher. It can monitor progress, be a personal tutor, simulate experiments, teach and be taught. It is a tool to be used in an appropriate way at an appropriate time to improve teaching and learning.

Still one must always remember that a computer is only a tool to assist the teacher to make the learning of mathematics more effective, more interesting and more enjoyable. Mathematics teachers must at all times take into account the objectives they are trying to accomplish when using the computer. If it is used, it must be used wisely to avoid any harmful effects, as using the computer to the exclusion of other methods can limit a pupil's experience. Resourceful teachers should therefore acknowledge those areas where the computer could enhance the education process and see to it that utilisation takes place to the full extent of its capabilities.

CHAPTER 4

INTEGRATION OF THE COMPUTER INTO THE MATHEMATICS CURRICULUM

Before any successful integration of the computer into the mathematics curriculum, the researcher feels that there is a need to examine the possible link between the nature of mathematics teaching and the computer activities described in Chapter 3. Also as some available models of instructional computing activities do not always match the instructional styles of the teachers nor the instructional needs of the pupils, there is a need to investigate different instructional methods of integrating the computer into the curriculum.

4.1 TEACHING STAGES FOR MATHEMATICS

Very broadly, mathematics educators are concerned with the developing of mathematical concepts and skills in their pupils. In order to help the pupils to understand, interpret and absorb the new knowledge into their existing cognitive structure, mathematics educators have to acquire a variety of teaching strategies because of the different learning styles of the pupils within the class. Instructional activities are therefore chosen for their relevance to mathematics, while an adequate range of teaching strategies provides variety.

However, Woodhouse and Jones (1988:385) believe that there are certain general stages of teaching when presenting and completing a mathematics unit over a period of time and that these stages may overlap or may be repeated within a lesson.

Fong (1989:159) supports this view with his description of a teaching and learning sequence of a mathematics unit. This teaching sequence includes an introduction, the use of strategies for the pupils to learn concepts and skills, providing material to practice and master the concepts, guidance and finally evaluating and testing the concepts. An awareness of these stages will therefore make it possible for mathematics educators to choose appropriate instructional methods to facilitate the teaching and learning sequence within a mathematics unit.

4.2 LINKING THE TEACHING STAGES WITH THE COMPUTER ACTIVITIES

How can the computer assist in the management of learning within this framework of the teaching stages of a mathematics unit? Fong (1989:159) summarised, as illustrated in Figure 4.2, how the various teaching stages within a mathematics class might link to the different activities of the computer.

Maths teaching mode	Computer activities
Stage 1: Concepts/skills formation	(1) Tutorial program (2) Demonstration program
Stage 2: Strategies, problem solving or skills learning	(1) Tutorial program (2) Simulation program (3) Instructional game program
Stage 3: Drill and practice	(1) Drill and practice program (2) Instructional game program
Stage 4: Evaluation of concepts and skills	(1) Computer managed instruction (CMI)

Figure 4.2 Linking the teaching model with the computer environment

The tutorial or demonstration programs can fit into Stage 1. At this stage the teacher's main concern is to introduce the pupils to new materials, problems, ideas and skills needed to master the new concepts. This process is most effective if it also involves pupil participation and discussions.

At Stage 2, the tutorial, simulation and games programs could be used to guide the pupils to understand the different concepts needed to learn the necessary skills. Also, at this stage, the computer could easily be used as a tool, as it allows the pupils to explore a variety of situations, test out ideas, study and develop new concepts. Ideally a type of expert system is necessary at this level, as the software program should be capable of not only asking pertinent questions about the concepts, but also analysing the answers to the questions and giving informed explanations for acceptable responses.

The drill-and-practice programs fit into Stage 3. These programs reinforce and consolidate the concepts, skills and routines already learned by generating numerous exercises for the pupils without becoming bored. A simulation in which pupils need to apply concepts and skills to solve problems is also very useful at this stage.

At the evaluation stage, besides the tutorial and drill-and-practice programs, a teacher could use specific CMI systems. Evaluation is necessary at this stage as pupils should be tested to see how much they have learned and assimilated. Unfortunately the available drill-and-practice programs are usually only used in testing lower level skills such as factual recall. To be of any real value at this level,

software programs should be devised to reinforce some higher level skills such as comprehension and evaluation of the developed concepts. (Woodehouse and Jones 1988)

4.3 INSTRUCTIONAL MODELS FOR INTEGRATING COMPUTERS INTO A MATHEMATICS LESSON

The use of the computer should give rise to a richer classroom environment as exciting new teaching approaches become possible. When planning the use of the computer for a specific teaching stage, aspects such as the following need consideration.

* The category of the available software for the instructional activities, viz. drill-and-practice, tutorial, tool, simulation, etc. should be determined. This will help the teacher to decide the stage at which the package could be used, i.e., as an introduction to the lesson, as drill and practice to reinforce new concepts or in problem solving situations to test the understanding of concepts.

* The teacher should bear in mind the objectives of the lesson when determining whether the software package should be used as remedial, supplementary or for other purposes.

* The teacher should decide whether to use the computers within a laboratory for individual/group work or within the classroom for use as an electronic blackboard for demonstrations, class discussions, etc., or maybe in small groups, within a classroom, for exploring mathematical

concepts. The technique applied will again depend on the teacher's objectives for the lesson, the available software, the location of the computers within the school, the stage of the lesson and the type of involvement required of the pupils.

Although there are many ways of using a computer within a lesson, the following four broad instructional models and management techniques seem to be used frequently.

(i) Computers situated in a computer laboratory and used for drill-and-practice, problem solving, etc. (see package no 1 in Chapter 5)

(ii) A computer situated at the front of the class with the teacher using the computer as a whole-class demonstration/teaching aid. (see package no 2)

(iii) A computer(s) situated at the side/back of the class and used by an individual pupil to support the work done away from the computer. (see package no 3)

(iv) A computer situated at the side/back of the class used by a group of pupils to carry out a mathematical task.

4.3.1 Using computers in a Computer Laboratory

According to Waits and Demana (1990:36) computer laboratories provide a setting for a guided-discovery model of instruction. As laboratory tools, computers assist in the exploration and discovery of concepts. The pupils work individually or in groups of two or three at each computer, with the teacher intervening from time-to-time to help the pupils understand or discover important mathematical concepts. To complete the task the pupils need to talk with

one another about the problem and help one another. The collaboration that takes place gives each pupil the opportunity to give help and to be helped in a non-threatening way.

The pupils usually come to the laboratory for a common mathematical purpose, for example, the practice of skills and the regular use of drill programs. They load the software and then follow the given screen instructions. A handout as opposed to reading the guidelines on a screen could be given to the pupils before using the computer. A pretest of the handout would ensure that the pupils are familiar with the handout before allowing them to use the computers. On the other hand, a carefully prepared worksheet accompanying the software will help the pupils understand or discover a given mathematical idea.

However a severe shortcoming is that this laboratory-based instruction is seen as a separate activity instead of an integrated part of an actual mathematics lesson. The pupils have to move out of their mathematics classroom into a computer room that has a totally different environment - a different physical layout, wall charts, etc. Therefore, according to Milone (1989:40), instruction often focuses on

> *computing as an independent process rather than a tool to assist learning or to reinforce what has already been learned.*

4.3.2 USING A COMPUTER AS A DEMONSTRATION AID

As a lecture-demonstration aid the activity centres around a single computer for the whole class. The teacher uses the computer within a lesson for the introduction or stimulation

of new ideas, for the investigation of data or for pattern recognition, etc. The teacher controls the computer, usually situated in front of the class, and acts as a facilitator of co-operative learning. All the information is entered on the computer keyboard and, depending on the size of the class and whether a large screen is available, is more readable and organised than is the case when using the blackboard.

Information to be demonstrated can be prepared beforehand and stored in files on diskettes. These demonstrations can include both text and graphics. Carefully prepared worksheets, with leading questions and open-ended questions could also accompany these interactive demonstrations.

This method can be exciting, highly interactive and visual when used for the demonstration of mathematical ideas, the setting of challenges, etc. It offers a novel approach and introduces a new dimension to mathematics. For example, a teacher, using the graphics capabilities of the spreadsheet, can quickly produce the graphs of $y = 2x - 1$, $y = 2x + 1$ and $y = 2x$. The subject matter can easily and rapidly be modified as the needs of the lesson determine during its progress. Careful questioning by the teacher should help the pupils discover the significance of the gradient and the y-intercept in the equation $y = mx + c$. This is clearly something that the teacher could not demonstrate as easily when using traditional teaching methods.

In this mode the computer is used as a form of teaching aid to help the pupils learn certain concepts. It acts as a neutral adjudicator by responding rapidly to questions posed

by both the teacher and the pupils. This stimulates the pupils to talk about what is on the screen, so the pupils become more open in their discussion and attempt a broader range of ideas. Furthermore, in contrast with computer use in a laboratory by individuals or small groups, this method allows the full participation of the teacher.

Given 'hi-tech' classrooms, the electronic blackboard arrangement has great potential for becoming an integral part of the mathematics curriculum as the computer, like an overhead projector, can form part of the daily lesson routine. It is a resource that pupils and teachers can use if and when the need arises to demonstrate or test an idea/technique.

Yet having a computer in the classroom can be distracting and create organisational problems, like whether all pupils can see properly, whether a large screen is available, etc. It also becomes an additional activity for the teacher to supervise and around which to prepare integrated lessons. This implies an increase in the detail of the planning by the teacher as it is necessary to know precisely how the computer will be used in the lesson.

4.3.3 Individual use of the computer in a classroom

This approach is possibly the easiest to organise. The computer is placed at the side of the classroom and used by an individual pupil to support or control their work. The pupils are encouraged to use the computer and the recommended software as and when the need arises. The associated software could, for example, take the form of testing

hypotheses for an investigation or be parallel work on a current topic, like checking the nature of the roots when using the formula for a quadratic equation. Initially teachers should not expect the pupils to, for example, invent and develop spreadsheets, but as they gain experience and gradually build up skills this could become possible.

In this mode the pupils use the computer as an information generator or a control device resulting in immediate feedback of the work undertaken in the class. Unfortunately there is not enough time for all the pupils to use the computer as a control within a lesson, although they could return in the afternoon for direct interaction with the program and control of their homework.

4.3.4 GROUP USE OF THE COMPUTER IN A CLASSROOM

This mode is similar to the method discussed in 4.3.3. The computer is again placed at the side of the classroom, but this time used by groups of pupils to pursue ideas brought to life by a micro-computer. The whole class does not have to focus on the computer at the same time. Wardle (1989:52) suggests that,

> *'if the rest of the class are working in groups this [mode] could well be part of a 'circus of activities'.*

In this mode, the computer is always accessible for use in the classroom with a variety of software at hand for pupils to use. This implies that if a mathematical problem has to be solved, the pupils will have a range of activities available from which to select the best method. This group-work around a computer allows opportunities for discussion

and co-operation whilst the pupils are exploring the best methods to solve a problem.

Unfortunately pupils working in groups at the computer can distract the other pupils working at their desks. However this distraction can be minimized if the computer is placed behind a screen with the monitor facing away from the desks.

4.4 CONCLUSION

Any argument for using a computer within a mathematics lesson is based on the assumption that the computer is an educational aid which can improve the effectiveness of conventional teaching methods. It could enhance and improve the pupil's mathematical knowledge and insight as, according to Marsh (1989:171), examples of software design objectives for mathematics education are

- *development of problem solving skills*
- *development of investigatory ability*
- *encouragement of the use of appropriate computational skills*
- *encouragement of the making of predictions*
- *enabling the testing of predictions*
- *promotion of awareness of inter-relationships of mathematical concepts*
- *effective communication in words, symbols and diagrams*
- *development of a positive attitude to mathematics as an interesting and attractive subject*

Ideally the use of the computer should be seen as an essential part of the whole mathematical programme, rather than simply an opportunity for innovation. It should be seen as an integral part of the total teaching resources of the mathematics department and planned for accordingly. Furthermore, Woodehouse and Jones (1988:388) state that

> *although the choice of software is highly important, the teacher's use of it is more important. ... the teacher is as important in the computer classroom as in the non-computer classroom, and has one more, highly flexible item in his or her pedagogical armoury.*

So a knowledge of the range of available mathematical software packages within the department will help teachers in their planning to combine computing with non-computing activities throughout the year.

However integrating the computer into the mathematics curriculum will not be easy. Not only will the integration of the computer require careful consideration, but close attention will need to be given to introductory and follow-up lessons. Most teachers will need time and support to become comfortable with this new teaching aid. In-service training will be necessary and appropriate syllabus materials and packages will need to be developed.

As a contribution towards meeting these requirements, the subsequent chapters will focus on the use of the computer as a tool within lessons. The electronic spreadsheet will be examined in detail to see how it can support and enhance the teaching of mathematics or challenge existing practice and thinking. Three spreadsheet packages, developed by the researcher, will be described and evaluated to provide some teaching material and ideas on how to integrate these packages into mathematics lessons.

CHAPTER 5

THE ELECTRONIC SPREADSHEET AS A TEACHING AID

5.1 INTRODUCTION

The electronic spreadsheet is one of the most popular software items available, particularly in business, engineering and industry. Arganbright (1984:1) argues that the electronic spreadsheet can also be used effectively and creatively in mathematics education.

Masalski (1990:1) sees some of the advantages of using the spreadsheet for the teaching and learning of mathematics as follows:

> * *The spreadsheet is readily adaptable for problems that are iterative, recursive, or tabular in conceptual format ...*
>
> * *The spreadsheet can enhance the user's insight into the development and use of algorithms and modeling.*
>
> * *The spreadsheet frees students from being hampered by laborious manipulations of numbers and allows them to concentrate on the mathematical problem itself...*
>
> * *The spreadsheet allows the students to see a progression of calculations on the screen as they are generated and permits students to change one variable at a time to see what effect the change has on the overall pattern ...*

While Leharne and Metcalfe (1989:143) mention, amongst others, the following benefits of the spreadsheet as a powerful tool:

* It is easy to learn and user friendly.
* No programming knowledge is needed or has to be learned.
* Most spreadsheet packages have similar features so that it is easy to move from one type of spreadsheet to another.

* Most spreadsheets can be used with wordprocessors and databases.

5.2 SPREADSHEET DESCRIPTION

What is a spreadsheet?

The spreadsheet is a numerical/mathematical environment that is accessed through a specifically designed program. It can be regarded as a large rectangular worksheet comprising of an array of labelled rows and columns that can hold data. The rows are identified by natural numbers and the columns by letters. The intersection of a column and a row forms a cell, identified by, e.g., B2 (see Figure 5.2).

	A	B	C	D	E	F	G	H	I	...
1										
2		B2								
3										
|										

Figure 5.2. Spreadsheet format.

Each cell can contain either a real number or a descriptive text determined by direct insertion of the values, or an algebraic expression which references other cells in the worksheet under consideration. The spreadsheet program then automatically calculates values for the expression in the worksheet using the values and information of the cells that are referenced and then displays the evaluated worksheet on the screen. The power of the spreadsheet rests in this ability to perform calculations by using formulas that are obtained from cells elsewhere in the spreadsheet.

A commercial spreadsheet program can have hundreds of these rows and columns. It also has the capability of protecting the entire worksheet, only a part of the worksheet or any cell from accidently being deleted or changed.

Placing the cursor on a cell that contains information, will cause the information or formula in it to appear near the bottom or top left of the screen image, depending on the commercial spreadsheet that is used. Although the default for the program tends to be the 'calculated mode', most of the available commercial spreadsheets will allow the user to switch between a displayed calculation mode and a displayed formula mode.

A user can change the content of a cell by positioning the screen's cursor on that cell and then entering a new number, label or formula. When this is done the value of each cell is automatically recalculated and the screen display instantly updated to reflect the new value. The user can see the immediate effect and the results of the change that is made. The electronic spreadsheet also allows the user to store formulas and data in files for later use. Users then restore the data and manipulate it repeatedly and in so doing build up meaning for themselves. In terms of this description of the electronic spreadsheet, when comparing the spreadsheet with other cheaper technical devices, the programmable calculator can only store formulas for recall whenever they are needed, whilst the calculator can neither store formulas nor data.

Electronic spreadsheets also have many other useful features, including replication, built-in mathematical functions, e.g.,

exponential, trigonometric functions, etc., and the ability to create graphs to visually represent the data in the worksheet. However a knowledge of the appropriate mathematical theory is required to enter the formulas and functions correctly before the spreadsheet can be used effectively. Details on these functions and many other useful features can be found in user guides, manuals, and certain books and magazines.

5.3 THE SPREADSHEET AND MATHEMATICS

Often within mathematics a large number of particular results has to be examined in order to arrive at a generalisation. This could involve the handling of large amounts of data or complex and lengthy calculations. This is where the spreadsheet could be used to investigate, to reveal and, if possible, to illustrate relationships and generalisations.

On the other hand, if the teacher or pupil does not have any programming knowledge, the spreadsheet offers an ideal opportunity to use the computer mathematically as it is easy to learn and requires no previous programming knowledge. But it still could not be used productively without an appropriate level of mathematical expertise.

According to Marsh (1989:22):

> *Problems which lend themselves to solution using a tabular format can be processed very easily on a spreadsheet in such a way that initial values, step sizes and other parameters can be changed with results generated immediately.*

The spreadsheet could therefore be regarded as a curriculum enhancer. It is dynamic and does the calculations much more rapidly than pen and paper methods. The pupils can examine

many results in a short time as the input values can easily be changed and the effect of the change immediately seen.

Furthemore the spreadsheet allows the pupils to ask 'what if?' questions while examining the effects of changing the various assumptions. So instead of spending much time on repetitive mechanical calculations and the plotting of graphs, the spreadsheet lets the pupils do the calculations quickly and accurately. The time needed to solve difficult computations is also decreased. This then provides time for trying different methods of looking at data and therefore an increased concentration on fundamental ideas, patterns and relationships. It must however be emphasised that the spreadsheet does not remove the mental thought associated with computation procedures nor the need for the plotting of graphs, only the drudgery.

Spreadsheets also allow the pupils to get a feel for generalisations so that the focus of the mathematical activity becomes an investigation of results. Devising a general rule is not an easy task for any pupil. Therefore providing an interaction with the computer, using the spreadsheet, to work out relationships can be a very important step to help pupils to formalise and generalise. So instead of replacing conventional problem solving activities, the spreadsheet could supplement them in a powerful way.

McDonald (1988:615) suggests that the spreadsheet allows teachers to choose more realistic problems without being disturbed by difficult calculations. It allows pupils to see

a progression of calculations on screen and patterns that develop. Also pupils can make hypotheses based on data and see the immediate effect of the changes made. So in a short period of class time the pupils can get enjoyment and a large number of inductive experiences in discovering new relationships on their own. Arganbright (1984:1) on the other hand states that the

> *... spreadsheet can be used for teaching mathematical modeling and problem solving as well as for the study and implementation of algorithms.*

Still according to Benn (1989:614) the full potential of the spreadsheet has not yet been explored within the classroom and that if given time the computer proficient teacher could develop a number of applications with relative ease.

A spreadsheet can calculate at high speed and is always reliable in its operation. It provides an opportunity for the pupils to build their own simple management system and to project the results of their decisions into the future so that they can observe the behaviour of complex systems. It also enables the pupils to define formulae which compute results from the input of available data. So it is easy to modify the data and to store data for use later.

The spreadsheet therefore supports the development and discovery of mathematical concepts, in particular, statistics, functions, polynomials and convergence and divergence of series. It in no way reduces the need for mathematical understanding on the part of the pupils, but encourages the pupils to be inquisitive and creative as they experiment with mathematical ideas.

The activities in which the spreadsheet is used to quickly generate data for pattern recognition, hypothesizing and verification may resemble experimental work in science. In this mode the computer serves as a mathematical laboratory or generator. This method is particularly useful for the inductive approach to generalisations of identities, rules, etc., and for an inductive investigation of the properties of functions. The pupils can for instance quickly deduce that sin x and tan x are increasing functions while cos x is a decreasing function for the interval [0 ; 90]. Also the ease with which the co-ordinate pairs of a specific function can be generated and at the same time the spreadsheet providing an immediate graphic illustration of the data of the function defined, can help the pupils in their concept formation of the new knowledge. On the other hand activities like the use of a pre-created template for the production of a linear graph, allow the pupils to explore the effect of m and c of the function, $y = mx + c$.

The researcher feels that this type of computer environment clearly supports the constructivist learning model. The spreadsheet requires planning and careful analysis of the subject matter by the pupil. This implies that it encourages systematisation, based on experience, of the existing set concepts of the pupil. The pupil engages in concept construction and concept testing that is aided by communication. So the new concept that is formed is not just memorised. In addition the teacher can always help the concept to be formed by encouraging the pupil to experiment and test concepts for validity and usefulness in practical situations. (Murray 1988:7)

5.4 THE SPREADSHEET APPROACH WITHIN THE CLASSROOM

The examples and activities mentioned in 5.3 provide some indication of the potential of an electronic spreadsheet for mathematics teaching and learning. This spreadsheet could be used by both the teacher for demonstrations and the pupil for problem solving and projects. When planning to use the spreadsheet within a lesson, the following methods could be employed.

(i) The teacher could create a template, including instructions, all the labels and formulas, in advance and save it on a diskette. The teacher or the pupils load the template, enter values or change the data and investigate the results. The teacher then leads the pupils using a guided discovery approach and worksheets to see general mathematical principles or draw specific conclusions.

(ii) The teacher could create and store a partially completed template on diskette and then ask the pupils to enter all formulas. Once the formulas have been entered the teacher guides the pupils to discover some general mathematical principles or patterns.

(iii) The pupils could construct their own templates using their methods for problem solving. An accompanying handout could stimulate the pupils to experiment and draw conclusions. According to Arganbright (1984:14),

> *the creation of a spreadsheet becomes a productive activity in its own right, reinforcing the concepts being studied.*

(iv) The pupils could create original pen-and-paper type algorithms within the spreadsheet and then use them for problem solving.

The choice adopted will depend on the complexity of the template, the pupils skill to use the spreadsheet and the time constraints of the curriculum. In addition the chosen method should complement the instructional model and management technique used for the lesson, as described in Chapter 4, Section 4.3.

Any completed or partially completed template should be so designed that the use thereof meets the need of both the teacher and the pupils. Also it should be able to be adapted to suit a class or a particular lesson that the teacher wishes to present. Furthermore, if the commercial spreadsheet incorporates graphics commands then the data of the function defined within the spreadsheet could be viewed graphically.

Using the spreadsheet approach within a class requires background reading, careful thought, forward planning and extra initial work by the teacher. The researcher suggests that mathematical spreadsheet packages should be developed and prepared to be used with a wide ability range. For the package to be effective in the classroom, it should be consistent with and very carefully integrated into the curriculum. It should be easy and attractive for both the teachers and pupils to use. The objectives for each package should be clear and meaningful to the teachers as well as pupils. The terminology and the language level should also

be tempered to allow for ease of understanding, interpretation and application depending on the ability level of the pupils. Furthermore, the package should at least include teacher notes, pupil handouts, any possible templates created in advance and the supporting formulae for the templates.

These packages, discussed in the subsequent chapter, are not intended to prescribe a precise model for the teacher to follow, but rather to convey ideas of what is possible when using the electronic environment. This then allows teachers to tailor or develop the packages to suit their own needs. Hence the packages should only be seen as a source of mathematical ideas for the teacher in the class. Besides, according to Coleman (1985:154), teachers welcome the opportunity to incorporate their own teaching style and methods onto a piece of software or into a computer lesson. Consequently they are then more likely to use it within the classroom.

The effectiveness of a package will always depend on the purpose for which it will be used as well as on the potential to develop certain capabilities in the learner for a given situation. It is also important to note that a particular package could be used in a variety of instructional environments, e.g., a teacher could use the package as an electronic blackboard to introduce the lesson topic and then have the pupils working in groups at the computer to complete the activity.

For this research investigation, three spreadsheet packages and fully prepared templates, stored on diskette, were developed. These template files explore simple and compound interest, find 'delta' and provide solutions to quadratic equations and investigate functional and graphical relationships as illustrated in Chapter 6. Also each package is used with a different instructional model as described in Chapter 7, Section 7.3.2.

CHAPTER 6

SPREADSHEET PACKAGES

6.1 SPREADSHEET PACKAGE DESIGN

When designing packages, consisting of spreadsheet templates, pupil worksheets, teacher notes and exploratory ideas, consideration should be given to the learning models discussed in Chapter 2 and the instructional models for the computer discussed in Chapter 4. This implies the nature of the activities the packages prescribe, the type of instructional objectives needed to stimulate the learner to want to learn and that which is intended to be learned by the pupil.

To promote the learning of mathematics, the package should be well-designed. It should be structured so that it will satisfy most of the pupils most of the time. It should not be too easy as it must allow the pupils to explore in their own way. If it is too difficult the pupils will waste their time and effort learning to operate the software instead of learning mathematics. In fact if it is too easy or too difficult it could lead to negative attitudes by the pupils as they could become bored or frustrated. On the other hand if the package is adapted to the individual needs and levels of learning of the pupils then the pupils could experience success and exhibit positive reactions.

A package should also carry only the essence of the mathematical task, that is, a single unit of subject matter. The key ideas and skills should be clear and manageable in

each package. The lesson should be carefully planned so that the pupil can follow a sensible path through the lesson. It should also be simple and unsophisticated so that the pupil can quickly understand the concepts. Unfortunately a computer program is often only judged to be good if it is long, very expensive, has menus, extensive graphics and covers a wide range of inter-related topics.

A possible approach to the design of the worksheets and the template and data files for generic software is illustrated (Figure 6.1) as follows:

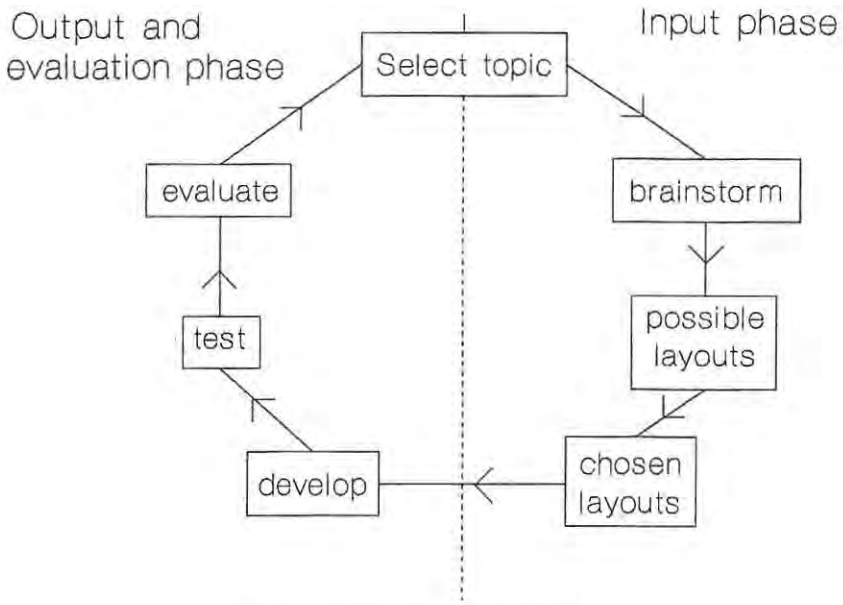

Figure 6.1 The design process

Establishing the topic, planning the lesson objectives and discussing, communicating and organizing ideas, layouts, worksheets, etc., should occur during the input phase. The output phase allows for the development of the package, the testing of the template files and finally the implementation of measures to simplify the design or to minimize any possible mistakes. The interpretation of the meaning of an

answer and the estimation of whether the answer is feasible, takes place during the evaluation phase.

When looking at the spreadsheet specifically, a well-designed template file, consisting of elementary stored formats and default settings, should be built as a set of functional blocks. Separate screens should be used for formulas, macro blocks, data entry and a central menu. Also a documentation screen, indicating the file name, objectives and possible instructions, is desirable. Furthermore for the lesson to be effective and to be practical it would be advisable to protect the entire template file except the area where the input values must be entered and/or changed. This will prevent any accidental deletion or change of the fixed data and formulas by either the teacher or the pupil.

According to Richardson (1990:97), the final template layout should be such that it could be used by the pupils or teacher, regardless of their familiarity and experience with a spreadsheet. User friendliness should be built into the program by including commands to load all the necessary files when first switching the computer on and by using limited input ranges that allow only specific data to be entered. The pupils then follow a preprogrammed menu for data input.

The final prepared template should be saved on disk and loaded into the computer whenever it is needed. After entering and analysing the data obtained, it can be printed and then transferred to the pupil's file if so desired.

The question that now arises is, which topic areas of the mathematics syllabus lend themselves to the spreadsheet

approach and design. Straker (1989:33), in her article Mathematics with a spreadsheet, suggests many mathematical applications of spreadsheets and the different approaches that can be used. Utilising some ideas of Straker (1989:35), McDonald (1988:617) and Masalski (1990:16), the following specific packages for different topic areas were developed. These packages are only representative of those that can be developed to explore mathematics using the spreadsheet and are designed to serve as models for similar packages that the teacher and/or pupil could develop.

The researcher makes the assumption that the reader or the teacher can operate the computer and has a good working knowledge of a spreadsheet. Also these examples do not require a specific commercial spreadsheet and do not have a 'correct' way to use the materials in the package. All the template figures used in the examples below are facsimiles of the screen images from the spreadsheet files and do not include the row and column labels. The formulas used for some of the templates are included as illustrations. With small modifications, these formulas can easily be adapted for any of the available commercial packages that contain the appropriate functions.

6.2 SPREADSHEET PACKAGES

6.2.1 Simple and Compound interest

This package is developed for a small section of the standard 7 syllabus. It creates a simulation of the types of investment in the real world and their effect on yield. It

also allows the pupils to explore realistic situations, e.g., inflation, bacteria and population increase, etc., while investigating 'what if ....' applications. Future work to which this concept leads is the section on geometric progressions at the standard 9 or 10 level.

Teacher suggestions:

1. Work through the package to familiarize yourself and to determine whether the activity is appropriate for the class.
2. The pupils must have a pre-knowledge of the basic concepts and algorithms of compound and simple interest.
3. Use this package as a whole-class demonstration lesson.
4. Template file construction: Draw up algorithms for both simple and compound interest. Also develop a spreadsheet template to indicate the progressive increase in value of the initial amount invested after successive years. For the comparisons of simple and compound interest to be effective put the algorithms side-by-side. The figure, Template 1, shows the completed algorithm and template before teacher interaction. The list, Formula 1, gives some of the formulas used in the template.
5. Hand out Worksheet 1 to the pupils. Let them complete up to STOP before loading the algorithm.
6. Load the template, complete the required input using ideas from the pupils and then use the spreadsheet to explore some options, e.g.,

   What if . . . . interest rates increase or drop?

   the amount is compounded monthly?

   the initial amount invested is increased?

inflation exceeds rate of investment?

population rate increases?

aids spread increases?

inflation continues and the effect of this on the bread/milk price?

7. The numbers used should be restricted to four significant figures.
8. This template can also be used as a control device in follow-up lessons, allowing the pupils to check their answers when manually consolidating the compound interest algorithm.
9. If the number of pupils in the class is more than 12, then the pupils may have difficulty seeing the monitor if no large screen is available.

WORKSHEET 1

STD 7 - ARITHMETIC

NAME: ..... DATE: .....

OBJECTIVE: To investigate the difference between simple and compound interest.

1. Draw up an algorithm (in words) to find the simple interest and the amount after t years.

   .....

2. Draw up an algorithm to find the compound interest and the amount after t years.

   .....

3. S. T. O. P. - explore simple and compound interest

4. Use the spreadsheet to find the compound interest on R 1 000 for 5 years at 10% p. a.

.....

5. S. T. O. P. - explore 'what if' questions

6. If interest is generated at 10% p.a. how long will it take for an investment of R 500 to double in value?

.....

7. (Teaser) Try to deduce a formula to find the compound amount after n years?

.....

TEMPLATE 1.

Screen 1

```
Filename: COMPI

          SOLVING SIMPLE AND COMPOUND INTEREST PROBLEMS

                    (Copyright: L. Funnell - 1990 )
=========================================================================

ENTER PRINCIPAL AMOUNT (P):       ?

ENTER RATE % p.a. (r)     :       ?

ENTER NO OF YEARS (t)     :       ?

                                SIMPLE INTEREST     COMPOUND INTEREST
                                      R                   R


Principal Investment                0.00                0.00

Interest for t years                0.00                0.00
                                  =========           =========

Amount after t years                0.00                0.00
                                  =========           =========

Press PgDn to investigate progressive compound amounts
```

Screen 2

COMPOUND INTEREST

PROGRESSIVE AMOUNTS

ENTER PRINCIPAL AMOUNT (P): ?

ENTER RATE % p.a. (r) : ?

ENTER NO OF YEARS (t) :

FIND r% OF P (I) :

ADD I to P - gives new P :

REPEAT for t YEARS (A) :

Press HOME to get to documentation screen

no years	AMT		
1	0.00	11	0.00
2	0.00	12	0.00
3	0.00	13	0.00
4	0.00	14	0.00
5	0.00	15	0.00
6	0.00	16	0.00
7	0.00	17	0.00
8	0.00	18	0.00
9	0.00		
10	0.00		

FORMULA 1

```
E19: +E13*E14/100*E15+E13
E21: +E19-E13
G19: +G13*(1+G14/100)^G15
G19: +G19-G13
F30: +$D$30*(1+$D$31/100)^1
F31: +$D$30*(1+$D$31/100)^2  etc.
```

6.2.2 FUNCTIONAL RELATIONSHIPS

This package gives pupils practice in determining functional relationships. It is at a standard 7 level and lends itself as an introduction to linear graphs. Here the computer is deliberately used to generate data pairs for functions that the pupils have not yet learnt. The purpose of the activity is that the pupils will explore patterns from these tables and then deduce the meaning of the function from the generated data and its corresponding graph. The pupils are required to investigate possibilities, make deductions and convince themselves and their group of what they find.

Teacher Suggestions:

1. Work through the package to familiarize yourself and to determine whether the activity is appropriate for the class.
2. The pupils must have a pre-knowledge of substitution and variables.
3. This lesson allows the pupils to work in small groups in a laboratory. The computer itself is used as a 'black box' whereby output values are generated for the input values and the task of the pupils is to determine the relationship between the input and output values.
4. Explain the lesson procedure to the pupils and then hand out Worksheet 2 beforehand so that they can become familiar with the instructions. Pupils must also be reminded to read the screen instructions carefully before they start.

5. Construct a template file and, if possible, the graphs of the relationships to be investigated. If the school only has single/double drive computers then make sure that there are enough program disks for all the computers.
6. In the pre-created template, the pupils are given an incomplete table of values and then challenged to determine relationships. They enter values for x and examine the corresponding values of y before 'guessing' the rule. Their rule must be checked by testing for additional values. The figure, Template 2, gives a screen layout after pupil interaction. The list, Formula 2, gives some formulas used in the template.
7. For the lesson to be effective
   - make sure the first relationship is relatively simple so that the pupils easily get the feel of what to do.
   - express y values in terms of variables hidden elsewhere in the spreadsheet so that the pupils familiar with spreadsheets are prevented from going to the y-column to get the relationship immediately.
8. Include a blank sheet of paper for the pupils to investigate their relationships. Pupils must also bring a calculator.
9. A follow-up demonstration lesson using the same template or another template to explore the effect of m and c, as discussed in Chapter 5, will reinforce, remediate or expand any experience gained.
10. Future possibilities are replacing x and y with distance versus time, etc.

WORKSHEET 2

STD 7 - ALGEBRA

NAME: ..... DATE: .....

OBJECTIVE: To determine the relationship between x and y.

1. Input different values for x. Look at the results that are obtained for y. Study each problem separately.

2. Check your 'guess' by substituting for other values in the same problem. Always write your 'guess' in the form y = ...

3. What is the relationship for

   Problem 1 ..... ?

   Problem 2 ..... ?

   Problem 3 ..... ?

   Problem 4 ..... ?

   Problem 5 ..... ?

   Problem 6 ..... ?

4. Press F10 to study the graphical illustrations of the first three relationships separately.

5. What is the shape of each of the graphs? .....

6. Make a small rough sketch of each graph next to the first three relationships obtained in 3. Compare each graph with the corresponding relationship that you obtained. What patterns (similarities and differences) do you notice?

   .....

   .....

7. (Extension) From what you have discovered, draw up your own relationship with its corresponding graphical illustration.

.....

.....

FORMULA 2

	variables hidden elsewhere			
	AF	AG	AH	AI
problem 1: +$AH$1*A30+$AI$1	problem 1:		2	
problem 2: +$AH$2*A30+$AI$2	problem 2:		2	-2
problem 3: +$AH$3*A30+$AI$3	problem 3:		-2	1
problem 4: etc	problem 4:		3	1
	problem 5:		-3	2
	problem 6:	1		

TEMPLATE 2.

Screen 1

```
Filename: func1

            EXPERIMENTING WITH LINEAR FUNCTIONAL RELATIONSHIPS

                        (Copyright: L. Funnell - 1990 )
 ================================================================

         Guess the rule used to match each y with each x

         by placing values in the x-column.  Write the

         relationship as y = ..............

         Hint: keep the x-value between -4 and 4


         CHOOSE SET 1 OR 2 :          For SET 1 press alt A

                                      For SET 2 press alt B

         Press HOME to get back to this screen
```

Screen 2

SET 1

x-value	PROBLEM 1 y-value	PROBLEM 2 y-value	PROBLEM 3 y-value
1	2	0	-1
0	0	-2	1
-1	-2	-4	3
2	4	2	-3
3	6	4	-5
-2	-4	-6	5

Press HOME to get documentation screen

Press Alt B for SET 2

Screen 3

SET 2

x-value	PROBLEM 4 y-value	PROBLEM 5 y-value	PROBLEM 6 y-value
?	1	2	0
?	1	2	0
?	1	2	0
?	1	2	0
?	1	2	0
?	1	2	0

Press HOME to get documentation screen

Press Alt A for SET 1

6.2.3 QUADRATIC ROOTS

This program is at a standard 8 or 9 level and performs the tedious arithmetic task of solving quadratic equations. It frees pupils to concentrate on choosing the variables a, b and c and then to study and explore the effect the discriminant has on the nature of the quadratic roots.

Teacher Suggestions:

1. Work through the package to determine whether this activity is appropriate for the class.
2. The pupils must have a pre-knowledge of the formula for solving quadratic equations and the classification of the number system. They must also be able to link this classification to the roots of a quadratic equation.
3. This package should be used as an aid in the class, either by the teacher to demonstrate many examples or by the pupils to control their pen-and-paper calculations. If the pupils' answers do not agree, it is easy and quick to repeat the input to control their work. The pupils therefore get immediate feedback and reinforcement.
4. Construct a template file so that the pupils merely have to insert the values for a, b and c in a quadratic equation. The discriminant and the roots are then automatically calculated. The figure, Template 3, gives a screen layout before any pupil interaction.
5. Use this program file as early as possible to facilitate the mastering of new facts. A likely method is to investigate and interpret the information obtained. The

included sample Workcard 3 allows the pupils to complete a table, with the aid of a computer, before attempting to interpret the information to find a rule. The computer is used as a control device before looking for patterns.

6. For a variation, allow the pupils to work in groups, some using the computer while the others use a calculator, before checking with each other.
7. The computer should be used, either by a teacher or a pupil, for only part of the time within the lesson. Make sure that the pupils read all the instructions carefully.
8. To allow for discussion and to draw conclusions on the nature of roots after computer usage, plan for a 60 minute session.

TEMPLATE 3.

Filename: ROOTS

Calculating the Roots of a Quadratic Equation:

(Copyright: L.Funnell 1990)

==========

The general formula of the equation $ax^2 + bx + c = 0$ is given by

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Insert values for a, b and c and then press F9 to calculate the roots.

a = ?

b = ?

c = ?

==========

Discriminant: $b^2 - 4ac$ = 0

Roots: x_1 = 0 x_2 = 0

WORKCARD 3

A. Complete the a, b, c, and delta column.

Use the computer to check your answer and to obtain the values for the roots.

Answers to 2 dec. places whenever necessary.

	a	b	c	delta b^2-4ac	roots x_1	roots x_2	classification of roots
1. $x^2 - 2x + 3 = 0$							
2. $2x^2 - 7x - 3 = 0$							
3. $2x^2 - 3x - 2 = 0$							
4. $2x^2 - 4x = -2$							
5. $4x^2 - x - 1 = 0$							
6. $3x^2 + 5x = 8$							

B. Summarise the relationship between delta and the classification of the roots.

CHAPTER 7

RESEARCH INVESTIGATION

7.1 INTRODUCTION

The objectives for this classroom-based research study were two-fold.

* To examine, implement and evaluate different methods of using the electronic spreadsheet as a teaching and learning aid within lessons for some sections of the mathematics syllabus.
* To plan, design, construct and set up a small-scale action research case study and to reflect on the action of applying spreadsheet packages within the lessons and, in terms of action research methodology, make adaptations to improve it.

The researcher decided to carry out the investigation in two phases.

* A pilot study to check on the appropriateness of the packages by asking the teachers and pupils involved to comment and indicate any adaptations to be made.
* The actual research study on the use of the three different spreadsheet packages.

This classroom-based action research approach was adopted to help the researcher to design, develop, conduct and evaluate lessons using computers as an aid in the teaching of mathematics. The investigation and the responses of the participants are therefore not reported as evidence that the approaches used will necessarily work for all teachers and

pupils, but are reported to inform teachers of apparent trends and possible problem areas for any subsequent research and improvements. The report also serves as a resource so that other teachers could try out the activities and ideas in the packages and then develop them for use in their own teaching.

7.2 RESEARCH DESIGN

The methodology chosen for this research study was a small-scale action research case study. Broadly speaking, action research embarks upon a course of action, critically assesses and reflects upon the action and its consequences and then reconstructs an interpretation of the action as a basis for further action. (Hopkins (1985), Cohen & Manion (1987)).

Action research is ideal for this type of classroom-based research as it is easily conducted in the classroom and provides a guide for teachers to critically examine their teaching and teaching methods used with the aim of understanding and improving them. The approach is flexible, adaptable and allows for any change taking place during the implementation. In addition it is co-operative and collaborative as it involves the pupils and other mathematics teachers in the evaluation of a lesson. The methodology used is also empirical as it relies on observation and behavioural data arising from normal classroom activities - information is collected, discussed, evaluated and acted upon.

This study was restricted to two senior secondary schools in King William's Town for convenience sake. The selected

schools were willing to participate in the small-scale action research case study and the following procedure was adopted. Three identical lessons were observed and analysed in each school, using a different instructional mode of the computer for each standard.

Three teachers were involved in the research study, the researcher, responsible for the complete design and implementation of the spreadsheet packages and two other mathematics teachers, one from each school. These teachers acted as non-participant observers and were responsible for identifying, recording and analysing the pupils' responses and reactions to each package.

This type of research did not lend itself to a quantitative and systematic approach. So to establish the validity and to correct any possible bias of the research, the technique of triangulation was used. This technique involves gathering information about a teaching situation from three different points of view, namely, the teacher/researchers', the pupils' and a non-participant observer's.

For this research study, the researcher recorded detailed interpretations of the classroom experiences, the pupils answered a questionnaire on the teaching material and method used and a non-participant teacher observed the teaching situation and classroom interactions.

More specifically, details of the instruments and techniques to gather information for this action research were as follows. It must however be pointed out that although these techniques are described individually, they did not take

place in an orderly and discrete manner, but were used eclectically and in combination.

* Field notes - An open notebook kept on the teacher's table, allowed the researcher to make, where possible, immediate scant notes on the general impressions of the classroom atmosphere as the lesson progressed. These notes detailing more fully the observations, incidents and reactions to this teaching method, were completed as soon as possible after each lesson.

* Questionnaires - At the end of each lesson the pupils answered a questionnaire containing specific questions about the teaching method and curriculum material. This provided feedback on attitudes, adequacy of the material, adequacy of the method used, ideas for improvement and conclusions. Their main use, however, was to obtain some form of quantitative data collection.

* Non-participant observer - This allowed the researcher to gather information for triangulation and permitted a more unbiased and objective method of data collection. Another teacher would be in the classroom only as an observer and would not participate in the lesson at all. This teacher concentrated on observing and recording the classroom atmosphere, the effectiveness of the teaching method, the use of the spreadsheet packages and the interaction between the teacher and pupils and between the pupil groups rather than on the lesson content. Also emphasis was placed on the fact that value judgements were not being made. The researcher reinforced this by

explaining to the pupils the purpose of having the teacher in the classroom for the lesson.

From all the data collected the researcher was able to generate some ideas about the teaching methods and about what was actually happening in the classroom. These ideas reflected the data and were an interpretation of it. By comparing and cross-checking the evidence and information obtained in the three ways explained, the researcher found that a pleasing amount of consistency existed between these recorded impressions. This suggests that despite the inherent limitation of the research design, the researcher was able to validate, test and refine the observations obtained from the three different sources.

7.3 PILOT STUDY

The main objective of the pilot study was to obtain information on the following.

- the pupils' reaction to the computer within a lesson
- the ease of keyboard usage
- the time needed to complete a lesson
- the time unavoidably lost during a lesson
- the group dynamics within the lesson on relationships

7.3.1 INSTRUCTIONAL MODEL SELECTION

Various instructional models and techniques of computer usage were studied. The eventual selection, to critically investigate the educational effectiveness of the electronic spreadsheet within a mathematics lesson, involved three approaches:

- using the computers in a laboratory in groups;
- using a computer as a demonstration aid;
- use of the computer by individual pupils within a classroom.

These modes (refer to Chapter 4, Section 4.3) were chosen for the research, in order to isolate meaningful methods of using a spreadsheet and then to report on the different instructional modes within the lessons. The report should therefore enable teachers to make comparisons between the different computer modes for future action.

During the pilot study, the laboratory instructional model received more attention on account of the availability and location of computers. Also the location of the computers within a laboratory for the selected schools necessitated adaptations to the classroom model as all the lessons had to be conducted in the computer laboratories. Computers and furniture had to be moved to simulate a classroom.

7.3.2 Preliminary Screening

Questionnaires

The questionnaires were printed in the form intended for use. During the construction of these questionnaires, an effort was made to ensure that the questions did not contain difficult or unclear phraseology, that the preceding questions did not influence an answer to a question and that the wording did not include bias or loading towards a particular direction.

One of the mathematics teachers involved in the research, examined the questionnaires and provided comment and

constructive criticism with respect to the content, wording, bias and presentation. As a result a small modification of some of the questions and the layout took place before the questionnaires were finally prepared for the pilot study.

Template files and resource material

Electronic spreadsheet template files were created for use with the different instructional models within the planned teaching lessons. Templates in this context may be considered as elementary stored formats with all the default settings common to specific applications, for example simple and compound interest. Careful attention was given to the design and layout of the template so that the final program was such that it could be used by the pupils, regardless of their familiarity and experience with a spreadsheet.

The design of the resource material and activities, consisting of the templates, pupil and teacher notes and worksheets for the spreadsheet packages, involved many decisions, for example the functions and level of complexity allowed for the relationships in the standard seven lessons and the avoidance of unnecessary screen instructions for the templates. Still, one must bear in mind that these packages are only a source of mathematical ideas and allow for flexibility of approach by the teacher and pupils.

Once again one of the mathematics teachers involved in the research, examined the templates and resource material and provided comment and constructive criticism with respect to the content, worksheets and presentation. As a result small modifications of some of the templates and additions to the

packages occurred before these packages were finally prepared in draft form for the pilot study.

Trial evaluation of the instructional models

In consultation with one of the other teachers concerned with the research, pupils from standards 10 and 8 of one of the schools were selected for the trial evaluation. These pupils represented a cross-section of the age and ability grouping for the particular standards.

The selected pupils had already completed the syllabus sections described in the spreadsheet packages. The researcher felt that a prime consideration for the trials was that the pupils were not to feel threatened by the mathematics involved, but that they should concentrate on whether this method of computer usage could have improved their initial grasp of the concepts when comparing it to the method used the previous year. The researcher explained this basic objective of the trial research to the pupils. The pupils were also informed that their interpretation and thinking was important if any modifications and improvements were to be made.

Three different lessons, each using a different instructional mode, were taught - one to the standard ten class and two to the standard eight classes. Each lesson comprised of a 40-minute period. One of the lessons, using a discovery and investigatory method, required a follow-up session.

An analysis of the questionnaires and the observations of each lesson to obtain the pupils' impressions and to test their understanding of the mathematical principles involved

and the application of the methods used, took place immediately after completion. For this pilot study another teacher did not act as an observer. This form of triangulation was, however, used in the main research study.

7.3.3 Assessment of presentation and responses

The questionnaires were studied and the responses assessed in terms of the objective specified for the pilot study. This resulted in the following specific observations, conclusions and decisions for future action and improvement.

* Each computer mode had a different working environment and classroom climate. But the teaching technique and the basic approach of the instructional mode used in each of the lessons was satisfactory.

* The group work and co-operation amongst the pupils was good. It allowed the pupils to learn from each other, try alternate ideas, etc., and at the same time allowed the teacher to engage in more effective communication with the children, monitor progress more effectively and retain a suitable working atmosphere.

* The groups should be organized into ability groupings when using the laboratory instructional model, as the faster workers and high ability pupils within the group tend to dominate or become frustrated.

* The pupils should be familiar with the guidelines and rules on behaviour, safety and methods of operation within a computer laboratory.

* The computer(s) should be loaded and set-up before the start of the period.

* Neither of the schools selected for this research has a large screen. When using the computer as an electronic blackboard, some pupils in the class had difficulty in seeing the monitor screen clearly. Therefore it was decided to have no more than 12 pupils at a time for this kind of lesson.

* Many of the pupils were not familiar with the keyboard layout so that it took a while before these pupils could do any meaningful mathematics. It was decided to ensure that all the pupils had experienced the equipment and been keyboard-familiarised prior to the lesson.

* Insufficient space was allowed for rough work on the relationships worksheet in the relevant standard seven lesson. The pupils need rough work paper to test their derived functions. So the teacher's notes should contain a suggestion that a blank working sheet should be included.

* The templates were developed on a colour monitor. As a result when these templates were used on an amber/green screen it became very difficult to see the movement of the cursor. The colours used for the templates had to be redefined for use on the mono screen.

* The layout and spacing for the responses to the questions on the questionnaire seemed to be in order. Extra lines had to be added to two questions in Questionnaire 3.

* The standard 9 lesson had to be at least 60 minutes to allow for discussion and eventual consolidation of any patterns found by the pupils. The standard 7 lesson on relationships had to be completed in two 40 minute sessions, while the lesson on interest only needed a 40 minute period.

* All the computers in the selected schools were located within laboratories. Unfortunately the use of a single computer as a teaching aid had to take place in the computer laboratory instead of in the classroom. It was decided to rearrange the laboratory as far as possible so that the room could simulate a classroom.

7.4 RESEARCH STUDY

7.4.1 PREPARATION OF RESOURCE MATERIAL

The spreadsheet packages were modified as discussed in 7.3.3 and prepared in draft form for the final presentation to the teachers and pupils involved in the pilot study. A discussion on these final drafts ensued with the mathematics teachers involved in the research. The aim of this discussion followed the same format as outlined in the pilot study and preliminary screening in 7.3.

Some minor modifications were again made to the packages, questionnaires and presentations. The appendix and Chapter 6, Section 6.2, contain the final version and layout of the questionnaires and the spreadsheet packages. This resource material was used in the main research study.

7.4.2 DETAILS OF THE SAMPLE

Both schools involved in this research are rural, traditional Girls' and Boys' schools respectively falling under the administration of the Cape Education Department, and they deliver instruction through the medium of English. These schools have also adopted and implemented the Model B method of enrollment of pupils, whereby the school and its Management Council make the decision to accept pupils of all races.

The pupils write the external Senior Certificate examination of the Cape Education Department and their mathematics results reflect standards ranging from equivalent to the provincial median to above the provincial median, for both the Standard and Higher Grades. No Lower Grade mathematics is taught in these schools.

With the exception of the one standard 7 class in school B, the sample from each school consisted of two standard 7 classes of mixed-ability groupings, while for the standard 9 classes, one group took mathematics on the Higher Grade and the other group took mathematics on the Standard Grade. The pupils in the standard 7 class from school B were from the middle to top achievement group. However the streaming used in this school is very broad so that even within this class there was a wide range of abilities. Also when looking at the ability groups one must always bear in mind that the standard 9 pupils elected to continue to study mathematics, while the subject is compulsory for all the pupils in standard 7.

A summary of the number of pupils involved from each standard in each school is as follows:

	std 7 i	std 7 ii	std 9	total
school A	28	12	17 (HG)	57
school B	27	12	15 (SG)	54
				111

7.4.3 PROCEDURES OF THE RESEARCH STUDY

After taking into account the suggested time allocation per activity, the size of the class for each instructional model and the other proposals outlined in 7.3.3, the following general procedures were adopted for each lesson.

* Prior to the lesson, time was devoted to an explanation on the background of the topic, the teaching method employed, the basic objectives of the research and the purpose of having another teacher (non-participant observer) in the class.

* The pupils were advised to read and follow the worksheet, workcard and/or screen instructions carefully. They were also encouraged to explore and evaluate their solutions whenever possible.

* The required computers were loaded beforehand, but the monitors were switched off.

* A questionnaire was handed to the pupils during the last 15 minutes of each lesson.

* The non-participant teacher sat in the class to observe the lesson in terms of the design as outlined in 7.2. The researcher met with this teacher as soon as possible after the lesson to discuss and record the observations and any developments and, if necessary, to effect any modifications before the next lesson.

This procedure generally proved to be satisfactory. A brief description of the method and approaches used to obtain the objectives for each of the lessons is given below.

* The first lesson for the research involved using one computer as an electronic blackboard for the demonstration of simple and compound interest and their effect on yield, to a standard 7 class. The demonstration was exploratory, with the teacher employing a 'what if ...' and 'suppose that ...' approach in order to try to make reality more visible to the pupils. A worksheet, with some closed and open-ended questions, was handed to the pupils before the start of the lesson. The researcher's field notes could only be written after the lesson.

* The second lesson dealt with functional relationships. A worksheet and a blank sheet of paper for each pupil was placed at all the working stations. A standard 7 class was divided into pairs according to similar mathematical abilities, as the approach utilised a guided-discovery model of instruction whereby the computer assisted in the exploration of these relationships. The pupils had to input x-values to obtain the y-values for each of the six problems. They then had to study the y-values in order to determine the relationship between the input (x) and

output (y) values. This relationship had to be checked by substituting for other x-values. On completion the pupils had to deduce the meaning of the function from the generated data and its corresponding graph.

The teacher/researcher moved around the classroom observing, making notes and helping the pupils to understand or discover important mathematical concepts whenever necessary.

* For the third lesson, given to each of the two standard 9 classes, one for each Grade, the computer was used as a tool. The computer performed the tedious arithmetic task of solving quadratic equations in order to allow the pupils to explore and interpret the effect the discriminant has on the nature of the quadratic roots. A workcard was handed to each pupil at the beginning of the lesson. The pupils had to read the instructions, complete the table up to a point and then use the computer as a control device to find the roots, before attempting to interpret the information to find the required patterns. The teacher/researcher moved around observing and helping for the first part of the lesson. Once the majority of the pupils had completed the workcard, the teacher led the discussion and questioned the pupils in order to draw conclusions, remediate and consolidate their findings.

After the completion of all these lessons for the research, the recorded impressions and the results from the three sources were compared, cross-checked and assessed as outlined in the subsequent chapter.

CHAPTER 8

ASSESSMENT, CONCLUSIONS AND RECOMMENDATIONS

In this chapter the results of the classroom practice and teaching methodologies when using an electronic spreadsheet, are examined. These teaching and learning methods are assessed according to the opinions of the pupils and teachers and the recommendations of the researcher, as reflected in the answers to the questionnaires, the current literature and the observations by the non-participating teachers and researcher.

From this assessment, conclusions are drawn and recommendations are formulated which hopefully should contribute to the development of viable classroom practice, with respect to the use of the computer spreadsheet as an educational aid, in mathematics.

8.1 DISCUSSION AND ASSESSMENT OF THE RESULTS OF THE RESEARCH STUDY

These results do not claim the objectivity to be found in a quantitative and systematic observation. They are subjective but are based on the observations and impressions obtained from three different sources.

8.1.1 OUTLINE OF THE ASSESSMENT

For the assessment, information was extracted from the responses and comments and recorded as follows. A description of some general findings, a brief summary of a few responses of the pupils to the same questions for each

lesson and some observations of the non-participating teachers, will be presented to provide a basis to illustrate the effect of the use of the spreadsheet as an aid within a lesson. This is then followed by a more detailed discussion and assessment of some of the findings.

8.1.2 General Findings

The three methodologies of using the spreadsheet packages as a teaching and learning aid within a lesson, proved to be effective and yielded some interesting information as discussed in 8.1.3. Also the design of the study was adequate for this type of research.

The decision to keyboard-familiarise the pupils prior to any lesson using the computer and to limit the demonstration lesson to only 12 pupils, as outlined in Chapter 7, Section 7.3.3, was fully justified. Meaningful mathematics could commence immediately and all the pupils could see the monitor far better than before.

The results from the questionnaires indicated that the majority of the pupils had little difficulty in using the computer, implying that the spreadsheet template environment seemed to be user friendly. All the computers worked well with no power failures occurring. In a few instances when the pupils were unsure of what to do, they pressed the help key (F1), not realising that this facility would only help them in the construction of a spreadsheet. Unfortunately because 88% of the computers in the two schools had single drives, the researcher had to supply the computer with the

second disk whenever the pupils used this key. However this delayed the pupils only briefly. Also some pupils were so keen to start using the computer that they went in 'cold' and did not read the worksheet/screen instructions carefully. This was more apparent amongst those pupils who use the computer often.

The success and enjoyment of each of the lessons is clearly documented by the responses of the pupils made to a questionnaire administered immediately after each lesson. Most of the pupils expressed similar opinions, although some were far more succinct than others. These opinions and comments were directed at the content of the work as well as at the usage of the computer and worksheet within the lesson. Of interest to note is that these enthusiastic responses were similar to other research findings (Orzech & Shelton (1986), Ball (1986)), when the computer approach was used as a teaching and learning aid within a lesson.

In support of the above statement, the following were some of the responses made by the pupils to the question, " What did you like most about this lesson? "

* "Being able to work out the answers on my own. Discovering the pattern and reasons for the answers without being taught it first. Working on the computer was a different approach."

* "That I got the answer right and I was able to use the computer to make sure of this."

* "Working on the computer was fun and challenging."

* "We could work together and figure out problems."

* "The satisfaction I got from getting the same answers as the computer."

* "I liked being able to see that things can be worked out. It made it a bit clearer in a shorter space of time."

* "When you teach yourself you remember it better. It was a change to normal maths classes."

* "You had to figure things out by yourself and you could work at your own pace in the group."

* "The finding out and teaching which we did in groups. Also checking whether we were right or wrong."

* "That we had a chance to use the computer."

* "It was interesting. The work goes faster and doesn't take a long time. Lots of different aspects can be explored in a short time."

In answer to the question " What did you not like about this lesson? ", the majority recorded null responses while it seemed as if others felt they had to give an answer, even if it was just to complain that the time was too short as they wanted to continue with the experimentation. However as observed from the responses reported below, it was also clear that a few pupils were not all that enthusiastic about certain aspects.

* "Waiting to use the computer."

* "The graphs - a lot more difficult to see patterns."

* "At times I wasn't too sure about what was going on."
* "I could not find most of the relationships."

The non-participating teachers' observations and comments were equally constructive and positive. A brief summary of the findings of these teachers is given below.

* Overall the pupils were eager at the start of the lesson and this did not decrease in any way towards the end of the lesson, except for some restlessness observed during the demonstration lesson.

* In general, the quality of the templates and worksheets was good, varied in content and allowed for a sequential flow through the lessons.

* The interactions amongst the pupils and between the pupils and researcher was open and encouraging.

8.1.3 Discussion of findings

As stated before, within the limitation of the research design, it was felt that the research study was successful and that it yielded satisfactory results. The following is an assessment and discussion of some of the observations and the implications for teachers that seem to emerge from a summary of the responses and observations.

* **Validity of responses**

  After a discussion with the other teachers involved in the research, it was felt that the pupils participated positively in the research and that the atmosphere while presenting the lessons was one of excitement, co-operation and interest. The responses and reactions seemed to be

genuine and sincere. What possibly contributed to this positive climate was that the pupils were also actively involved in the research investigation to improve the teaching-learning situation. This aspect is also highlighted by some research findings described in Hopkins (1985) and Hustler, Cassidy & Cuff (1986).

However some difficulty was experienced when using the computer as an electronic blackboard within the lesson. There was a general restlessness in the class, particularly towards the end of the lesson. This could perhaps be blamed on the fact that no large screen was available and as a result the pupils had to stand close together in order to see the monitor. Also the researcher's back was turned to the class. Still this restlessness did not seem to influence the pupils' responses to the questionnaire or their genuine interest in the investigation of the compound interest effect on real life financial computations.

* **Initial reactions**

Apart from the standard 9 Higher Grade class in school A, the other classes were normally taught by the non-participant teachers involved in the research. As a result the pupils were, in general, familiar and comfortable with the presence of their own teacher within the classroom. Nevertheless the teacher's presence did initially disturb the relationship between the researcher and the pupils, but, very quickly, as the lesson progressed the pupils tended to ignore the teacher's presence and settle down to work.

Also, even though the majority of the pupils were acquainted with the researcher, and the pupils in these two schools were subjected to a variety of teaching methods, there was an initial hesitancy and excitement in their reaction to 'the stranger' and to use of the computer within the lesson. This hesitancy seems to indicate that either the pupils were traditionally waiting to be told that they may begin or what to input on the computer, even although the worksheets were handed out, or that they were still not sure about the instructions. The latter was confirmed by a few pupils in answer to the question, "Did the teacher explain properly how to use the computer template/program?" Once overcoming this hesitancy the pupils confidently began discussing and experimenting within their groups, evaluating answers for themselves or offering open-ended questions, depending on the applied computer methodology for the lesson.

* **Methodology difficulties**

Although, in general, the reaction to the computer and results of the use of the computer in the mathematics class were very positive, highly motivating and productive, an assessment of the three computer methodologies did raise a few negative issues that have implications for the teacher.

- The pupils do not read or follow the screen and worksheet instructions properly.
- If the majority of the computers in the laboratory have single drives, the teacher may encounter some problems

when the pupils switch between the data and the graphics display screen. Another disk has to be inserted whenever this occurs, implying that all pupils should be skilled in disk handling procedures.

- Using the computer as an electronic blackboard may be very difficult within an ordinary class, without a large screen. The teacher may experience a great deal of restlessness and unnecessary talking.
- When using the computer as a control device, a few computers should be available, else the pupils will have to wait their turn to use the computer thereby wasting valuable time. This all leads to frustration as noted by the comments of a few pupils on the questionnaire.

An awareness of these issues should however lead to a resourceful teacher modifying the lesson material and methods to accommodate and solve these minor obstacles.

* **Content difficulties**

All the pupils had great difficulty, in Lesson 2, in finding the similarities and differences between the actual algebraic relationships that they had obtained and their graphical illustrations. Of interest, however, is that the brighter pupils, after using the computer, had no difficulty in writing down a linear relationship and then sketching its corresponding graph.

Still one must bear in mind that this lesson was only meant as an introduction to linear graphs and that the pupils had not yet encountered any informal sketching of relationships. The researcher suggests that a small

modification takes place in that Questions 6 and 7 of the worksheet are swapped. Before the pupils then attempt the last question, the teacher highlights the characteristics of the shape of a linear graph possibly using another spreadsheet method as outlined in Chapter 5.

* **Inductive approach**

The computer methods used in Lessons 2 and 3 made it possible for the pupils to experiment using an inductive approach in order to find the relationships or patterns. The speed with which data was generated by the computer provided the necessary time for the pupils to study the information. The satisfaction of finding these patterns for themselves can be detected from some of the pupil comments in 8.1.2. This method is a change from the traditional deductive methods usually used within mathematics lessons.

* **Groupwork and communication**

Although the computer was used as a teaching and learning aid within the lesson, it also provided an environment for the pupils to work together, particularly in Lesson 2. The pupils were involved in developing strategies, discussing methods and results and testing the ideas. The enjoyment of working in groups is evident from some of the comments in 8.1.2.

An added benefit of working in groups is that this method allowed the pupils to practice their communicative skills and it also provided them with the opportunity to express and communicate their ideas and results mathematically as pointed out in Chapter 2, Section 2.1.1. This observation

supports Wright's view (1988:43) that using a computer within a lesson promotes discussion and investigational work. However, it contrasts with the fear and concern, expressed by some participants working independently within the investigation carried out by Stoker and Robertson (1989:373), that the computer gives inadequate opportunity for pupil discussion and interaction.

* **Groupwork and confidence**

The use of the computer also seemed to allow the pupils to become more independent and willing to explore alternate solutions to problems. As the relationship lesson progressed the pupils appeared to become far less reticent about discussing their own views within their groups and more open in their approach to exploring, interpreting and testing the information generated by the computer within the lesson. Furthermore the researcher seemed almost to become a member of the group in that the pupils openly responded to help and intervention whenever it was needed.

Another interesting development was that the standard 9 lesson, involving the individual use of the computer as a control device, spilled over into a discussion within small groups for the interpretation of the instant results obtained from the computer. Unfortunately to the frustration of some pupils, because of time, the researcher had to intervene and draw conclusions before the end of the double period.

This observation suggests that when pupils are presented with problems using discovery or inductive methods, they need time to develop their conception of the problem and

that they prefer to discuss their ideas within small groups. Therefore teachers should allow the pupils this time to think and discuss before offering any guidance. Still the teacher should intervene by questioning the pupils within the group before their failure to progress lasts too long, else these pupils will tend to believe that they are unable to solve problems.

* **Teacher and pupil roles**

An observation made by the non-participant teachers was that the teacher's and pupils' roles within the classroom are different. The role of teacher seemed to change from a source of knowledge only to a facilitator of the learning process and motivator of the pupils, and the role of the pupils changed from passive receivers of knowledge to active participators in their own construction of knowledge. The teacher was seen as someone who helped and guided them to obtain the lesson objective. This approach, with the focus on the pupil as an active learner, has implications for the teaching methods used within the class.

These findings were in agreement with the description of the approach outlined in Chapter 3, Section 3.1.2 and in Chapter 5, when using the computer and more specifically the spreadsheet as a tool within a lesson.

* **Motivation and attitude**

The computer was also seen to have a strong positive effect on the pupil's motivation and attitude to exploring, evaluating and learning mathematics within the lesson. A meta-analysis of this observation showed that

the computer seems to hold a fascination for most of the pupils, in particular amongst the standard 7 boys. This was clearly illustrated when 58% of the pupils responded positively to the question " Do you think that all your mathematics should be taught on the computer? "

These positive responses ranged from explaining that the traditional "maths lessons were boring" and that computers are "fun" so they "would enjoy mathematics more" to, "it will be faster and you can help yourself without having the teacher checking every sum" and "it helps you to think more."

However the negative comments from the pupils were far more perceptive when they stated that "it will get monotonous", "we need to understand how to work out the problem step by step" and "not all maths suits the computer."

* **Individual attention to pupils**

The weaker pupils seemed unable to fully comprehend the concepts or to follow the instructions, as they were regularly seen to get help from the brighter pupils or from the researcher. This inability prevented these pupils from being able to find satisfactory relationships or patterns or to complete the worksheets.

However an unanticipated bonus of using the computer in Lessons 2 and 3 occurred, in that it appeared to afford the researcher some freedom to deal with other aspects of teaching. The researcher was able to observe the pupil group interactions far more closely thereby unconsciously

getting to know the pupils as individuals far better than before. In addition, the researcher was able to give the less able pupils immediate and extra guidance whenever it was needed. It was found that these pupils were capable of finding relationships and patterns, although their pace was much slower, their results and understanding more limited and some could not complete the worksheet in the allocated time. This freedom also made it possible to give greater attention to the needs of the individual pupils. In one case, when using the computer as a control device, a pupil found that all her answers were incorrect. The researcher was able to give immediate help and discovered that this pupil actually used her calculator procedures incorrectly.

The implication for the teacher is that when using this method of instruction (mastery learning within groups), differentiation can occur within the lesson as each group of pupils, with similar abilities, proceed at their own rate. Also this method could be effective when pupils taking Mathematics Higher Grade and others taking Standard Grade are grouped together within a class. Furthermore to aid in this differentiation, the worksheets could be graded or separate worksheets could be developed for pupils taking either Higher or Standard Grade Mathematics.

8.2 CONCLUSIONS

This research project set out to investigate the potential of the computer spreadsheet as a learning tool in some sections of the Senior School Mathematics syllabus. The researcher

felt that despite the inherent limitations of the research and the time available, the objectives for the investigation, as stated in Chapter 7, Section 7.1, had been attained. From this study it appears that the structure of the lessons, the lesson material and the computer methodologies implemented to investigate the potential of the spreadsheet as a teaching and learning tool had been satisfactory.

A central theme that seemed to emerge from this research is that the teacher is the deciding factor in whether the use of the computer as an aid within the lesson will be a success. The computer can help the pupil to learn faster, maintain longer attention spans and become more interested in learning, but the quality of the learning ultimately appears to rest with the teacher. Without guidance the pupils could acquire experience with new concepts but with guidance the pupils learn to associate this new knowledge with any existing underlying concepts.

Research has put forward many ideas and has made many claims (see Chapter 3, Section 3.2) concerning the potential computers have for enhancing the teaching and learning of mathematics. Many of these potential environments and favourable opportunities were observed and identified by the pupils and the non-participating teachers. Still the success of a lesson appeared to depend on the quality of the spreadsheet material, the classroom management of the computer and the methodologies used.

However when evaluating learning supported by the spreadsheet, it would be foolish not to take into account that the calculator or graphics calculator, which is smaller and cheaper than the computer, may be just as powerful a resource for the instructional methodology of the teacher for a particular lesson. Murray(1988:8) in fact suggests that it would be humiliating to come to the conclusion that many computer instructional environments made available at a great cost can be replaced by calculators at a fraction of the price with a far smaller possibility that the pupils will be forced into types of learning that will be unsuited to their needs.

8.3 RECOMMENDATIONS

Technological developments, like the computer, have some implications for classroom practice in mathematics as they make available alternative teaching and learning strategies. Therefore it seems logical that the methods concerning the teaching of mathematics should be examined and constantly adapted according to the latest technological developments and needs of the modern world. Below are some recommendations to provide a broader base for the use of computers within mathematics lessons.

* **Involve practising teachers in the development of computer packages**

  Research undertaken by Plomp, Pelgrum and Steernman (1990:165) indicated that the lack of suitable software and the poor quality of software were the main inhibiting factors when using the computer in Dutch schools. Also

Benn (1989:613) warns that it is unlikely that good software specifically designed for educational use will be plentiful in the future. This implies that the teachers will have to consider developing their own software if a commercial package cannot be adapted.

The spreadsheet packages described in Chapter 6 are good examples of some software development for mathematics, without the teacher having to be a skilful computer programmer. The researcher advocates that mathematics teachers become involved in producing similar packages in areas of mathematics that lend themselves to this type of development. These packages could then serve as a bank of resource material that becomes available to teachers within the schools.

A possible method to promote the development of computer software for mathematics could be as follows. Mathematics teachers within an area could attend workshops at the Teacher's Centre to create, for example, spreadsheet packages. The workshops could serve as an opportunity for teachers to identify areas to develop, to discuss ideas, to acquire techniques and methods that could be applied within the classroom and to learn from each other. Subject Heads could also run similar workshops on a smaller scale, within their mathematics departments in order to create and/or evaluate computer packages.

* **Broaden mathematics teachers' training in subject methods at tertiary institutions**

Newly trained teachers appear not to be adequately equipped to develop 'utility' software packages for

mathematics or to cope with the educational use of the computer as an aid in the teaching and learning of mathematics.

Although many of the teacher training institutions in South Africa incorporate computer literacy, in the widest sense, within the curriculum, these teachers need more than this. In fact, Benn (1989:614) maintains that courses to guide prospective teachers in the educative use of the computer and the development of software for a subject within a school are required.

The researcher is aware that not all schools have computers. However more and more schools are acquiring some computers either through their parent body, outside institutions or the educational authorities. The researcher therefore suggests that there is a pressing need at tertiary institutions to examine ways and means to ensure that mathematics curriculum development in computers is broadened to assist the prospective mathematics teachers.

* **Encourage teachers to read journals pertaining to mathematics and computers**

Mathematics and computer journals relating to education play an important role in curriculum development. Since new developments are continuously taking place, informative articles are essential to keep teachers up to date. According to Bell (1978:428) many new journals and magazines contain contributions from teachers and pupils about how computers can be used to help learn mathematics or how pupils can use computers to try to understand those

concepts that are difficult to learn in mathematics. These journals and magazines should therefore be available to teachers to arouse their interest in the use of the computer as a teaching aid.

The researcher recommends that special attempts should be made by mathematics teachers, prospective mathematics teachers and subject advisers to read computer and mathematics education journals to find new ideas and computing material to supplement textbooks and teaching methods in order to improve the quality of their teaching.

* **Appoint a computer assistant at schools**

The present mathematics syllabus is demanding on both the teachers and the pupils. Introducing the computer as an additional resource to enhance and extend the quality of the teaching and learning and to make the subject more interesting, as indicated by the findings in 8.1.2, not only increases this demand but also presents many organisational problems. This is mainly because of lack of time, very few free periods, the non-availability of a computer within the classroom or that the computer laboratory always seems to be occupied. Also time is wasted to keyboard-familiarise some pupils, as reported in Chapter 7, Section 7.3.3.

The appointment of a computer assistant to a school will greatly facilitate the teacher's task when using the computer(s) as an aid within a lesson. The duties of the assistant could include, amongst others, computer and disk maintenance, the setting up and loading of the programs, assisting the teacher during the instruction, providing a

timetable for the computer room and to keyboard-familiarise the pupils within a computer literacy program for the school. In addition the assistant could be responsible for the general administration of the school's database and the computerised reports.

The researcher suggests that the Education Authorities should investigate the appointment of computer assistants to schools, notably to those schools whose parent body has already purchased computers or schools who have been provided with some computer equipment by private companies or education departments. The assistant could possibly be phased in over a period of three years as was the case when laboratory assistants for the sciences were introduced to the secondary schools for Whites in the Cape Province in the 1980's. Furthermore in-service training on the general aspects of computer procedures could be arranged for these assistants.

8.4 CONCLUDING COMMENT

An attempt was made in this research to provide some classroom-based resource material when using the computer spreadsheet within the mathematics classroom, firstly, by reviewing the nature and aims of mathematics, secondly, by illustrating the potential of the computer and spreadsheet and, thirdly, by critically assessing and reflecting upon the classroom experience when using this material. The researcher makes the tentative claim that this investigation of the use of an electronic spreadsheet as a teaching and learning tool within a mathematics lesson exposed some areas

of interest and also emphasised the complexity and importance of the task of the mathematics teacher to maximise the potential of every pupil within the class. The researcher is therefore hopeful that this study will contribute to the development of a more successful classroom practice when using a computer in mathematics.

APPENDIX

QUESTIONNAIRE 1

STD: _____ **NAME:** _____

1. Did the computer help you to consolidate your understanding of simple and compound interest? _____

   How? _____

   _____

   _____

2. Would you like your teacher to use the computer more often when teaching mathematics? _____

   Why? _____

   _____

   _____

3. Do you think that <u>all</u> your mathematics should be taught on the computer? _____

   Why? _____

   _____

   _____

   _____

4. What did you like most about this lesson? _____

   _____

5. What did you not like about this lesson? _____

_____

6. What would you do differently in this lesson? _____

_____

_____

QUESTIONNAIRE 2

STD: _____ **NAME:** _____

1. Did the teacher explain properly how to use the computer program? _____

2. Did the work with the computer help you to guess and interpret the functional relationships? _____

   How? _____

   _____

   _____

   _____

3. Did the use of the worksheet as an aid help you to find any patterns better?

   _____

4. Would you like your teacher to use the computer more often when teaching mathematics? _____

Why? _____

_____

_____

5. Do you think that <u>all</u> your mathematics should be taught on the computer? _____

Why? _____

_____

_____

6. What did you like most about this lesson? _____

_____

7. What did you not like about this lesson? _____

_____

QUESTIONNAIRE 3

STD : _____ NAME: _____

1. Did the use of the workcard as an aid help you to find the patterns better? _____

2. Did the computer help you to consolidate your classification and generalization for the nature of roots? _____

How? _____

_____

_____

_____

3. Would you like your teacher to use the computer more often when teaching mathematics? _____

Why? _____

_____

_____

4. Do you think that <u>all</u> your mathematics should be taught on the computer? _____

Why? _____

_____

_____

_____

5. What did you like most about this lesson? _____

_____

_____

6. What did you not like about this lesson? _____

_____

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