INTRODUCING COMPUTERS INTO THE MATHEMATICS CLASSROOM:

A CASE STUDY

By

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ABSTRACT

This research study is concerned with the introduction of computers into a mathematics classroom. The study investigates the teaching of a graphing unit in the Mathematics 11 curriculum in a computer-enhanced setting and is framed within four research questions. The study investigates the features that emerged in a computer-based mathematics classroom, whether the teachers and students adapted to such a setting, and the advantages and disadvantages experienced by both groups.

Two teachers and their students were involved in this study. The mathematics classroom was equipped with 16 networked computers and a teacher workstation outfitted with an overhead projection device. The computer was used by the teacher as a demonstration tool and by the students as an aid to completing assignments. The students usually worked in small groups of two or three. Over a period of two weeks three mathematics classes were observed. The data collected during this period consist of detailed descriptions of events and people, as well as analytic ideas and personal impressions.

At the conclusion of the two week observation period, 11 classes had been observed and ten salient features emerged in the analysis of the data. The site and the software seemed to have the greatest influence on the introduction of
computers into the mathematics classroom. Cooperative learning also played a major role in the computer-based classroom. It was also shown that teachers require in-service training in the use of computers; they need to develop materials and tests to correlate with the software and the curriculum; and they need teaching assistants to help implement and monitor computer related activities.

This study illustrated the first steps towards fully integrating computers in a mathematics classroom. The teachers modified their teaching format slightly with traditional teaching methods dominating most of the lessons. They realized the potential of using computers and remained challenged to develop their use. Integrating computers in the mathematics classroom is a realistic goal; this research study suggests that the process can only proceed one step at a time with careful planning and clear goal setting with regard to teaching and evaluation objectives.
# TABLE OF CONTENTS

## ABSTRACT

PAGE ii

## TABLE OF CONTENTS

PAGE iv

## LIST OF TABLES

PAGE vii

## LIST OF FIGURES

PAGE viii

## ACKNOWLEDGEMENTS

PAGE ix

## CHAPTER

1 **THE PROBLEM** ................................................. 1
   Background.................................................. 3
   Educational Significance of the Study..... 5
   Statement of the Problem ......................... 11
   Research Questions ................................. 12
   Method of the Study ................................. 12
   Limitations of the Study ......................... 14

2 **REVIEW OF THE LITERATURE** .......................... 16
   Educational Innovation and the Challenges of the Changing Mathematics Curriculum.. 17
      Potential of Computers in the Mathematics Classroom......................... 17
      New and Traditional Programs ................. 19
      Implications for Teacher Training ................ 21
      Changing Roles for Teachers and Students.............................................. 22
      Cooperative Learning ........................................ 24
      Teacher Decision-making ........................................ 25
      Summary................................................... 29
   The Effects of Computers on Classroom Instruction In General .................. 30
      Cooperative Learning ........................................ 31
      The Integration of Computers In Classrooms............................................. 33
      Summary................................................... 41
# The Effects of Computers in Mathematics Classrooms

Computer Use and Availability
Achievement and Attitudes
Cooperative Learning
Summary

Summary of the Review of the Literature

## Method and Procedure

The Case Study Method

The Site
- The Teachers
- The Students
- The Course and the Software

Data Collection and Analysis

## Results

Introduction

A Chronological Log of the Data
- Observation 1
- Observation 2
- Observation 3
- Observation 4
- Observation 5
- Observation 6
- Observation 7
- Observation 8
- Observation 9
- Observation 10
- Observation 11

Summary

## Summary, Conclusions, and Recommendations

Summary of Observations
- The Site
- The Teachers
- The Students
- The Course and the Software

The Research Questions
- Salient Features
- How the Teachers Adapt
LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. A chronological log of the observations</td>
<td>115</td>
</tr>
<tr>
<td>2. Salient features of computer use</td>
<td>116</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The 8x5 timetable</td>
<td>59</td>
</tr>
<tr>
<td>2. Site plan</td>
<td>60</td>
</tr>
</tbody>
</table>
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CHAPTER 1
THE PROBLEM

This study investigates the introduction of computer technology into a mathematics classroom. The Underachieving Curriculum (McKnight et al., 1987) suggests that "technology, including calculators and computers, should find an appropriate place in the mathematics classroom. The use of such technology will promote the upgrading of the mathematical content of the curriculum as well as assist in the effective teaching of that content" (pp. 116-117). The 21st century is quickly approaching, and technology has taken a giant leap into the classrooms of British Columbia. New instructional aids have arrived in the form of computers of varying types, sizes, and speeds. Along with computers have come video disks, CD-ROMS, hyper-media, and many other confusing, yet exciting technologies. Ragsdale (1988) states that these new media will reshape societies, their governments, bureaucracies, and institutions.

In this age of the Information Revolution, many of the needs our society creates are easily met by the computer. Technology plays a dominant role in our day to day transactions, yet the relationship between most teachers and computers is a vicarious one. That is, most teachers have only heard or read about the overwhelming advances of computer technology in Western society; few have experienced them. On the other hand, many teachers do have and will have the
opportunity in this decade to experience the technology of the microcomputer.

Yet the argument rages on within the educational community as to the value of computers and accompanying software. For example, some teachers fear that the adoption of a new application-based curriculum will increase the demands placed on them in terms of flexibility and creativity (Fey, 1984). Pea and Sheingold (1987) observe that the broad scale changes at the classroom level, much less than at societal level, appear to be slow to emerge and elusive to study. The National Council of Teachers of Mathematics (1991) urges strongly for mathematics teaching reform based on developing students' mathematical power, which is defined as the ability to reason and explore logically, to solve non-routine problems, and to connect mathematics with other intellectual activities. Although the controversies support and oppose the adoption of technological changes, the professional standards document (National Council of Teachers of Mathematics, 1991) argues that a classroom environment must be created that fosters these new ways of thinking about and approaching mathematics. Technology is only one new tool that can help students pursue such mathematical investigations. Upon reading this and other studies, the reader must decide about the value of computers, about whether teachers' fears are justified, and about the implications of mathematics teaching reform.
Background

The decision to investigate the use of computer technology in the classroom evolved from a keen personal interest in computer technology for the past eight or nine years. Initially, this interest was manifested in the form of support for the teaching of computer literacy in the secondary schools and in the teaching of computing studies and computer science courses. The success of these early endeavors was gauged by the steady increase in enrollment in these elective courses and in the rise in the general level of computer literacy in the student population. However, the maximum educational impact of the computer (as asserted by Howson & Wilson, 1986; Ragsdale, 1988; Heid, Sheets, & Matras, 1990; Fullan, 1991) lies in its potential as a tool to enhance student learning not as an object of study itself. In order to actualize this potential, computer technology must be integrated with other means of instruction in standard educational settings.

Mathematics was chosen as the curriculum area for the study for several reasons. In the early 1980s, computing science was under the jurisdiction of the mathematics departments in many secondary schools. Thus the researcher, having access to the computers used for computer science, was able to experiment with a single computer in her mathematics classroom. The software which was available for use on the Apple IIe computer was limited, but the author maintained her
interest, as she could see the potential for demonstration, especially for the teaching of graphing techniques in algebra. She had attended many presentations and workshops on the use of specific pieces of software, but she was curious about how the use of the computer and the software could be incorporated into the regular classroom routine. How could the computer, or computers if one was fortunate to have access to more than one, be included in the normal classroom routine? How could the computer be used effectively other than being a reward for the students finishing their assignment early? How could the computer be used for the weak students so that they are not penalized by having to finish in-class assignments at home? Would the teacher be able to finish the curriculum if time was allotted for computer use? These questions always weighed heavily on the mind of the author.

In the fall of 1989, Lord Byng Secondary School in Vancouver, B.C. entered into a joint study with IBM Canada to use IBM hardware and a software package called the Mathematics Exploration Toolkit (MET) (Wicat Systems Inc., 1988) in a networked setting. IBM provided 16 PS/1 computers networked to a central fileserver and Lord Byng Secondary was licensed to use the MET software. The MET software is a computer-based algebra system which has the capacity to perform symbolic manipulation in algebra and calculus, as well as the capacity to graph various equations. The researcher was a teacher at Lord Byng Secondary at that time and saw the joint study as an excellent opportunity to conduct a study of the use of
computers in the mathematics classroom. The researcher was interested in observing various aspects of introducing computers into a regular classroom setting, from the technical aspects of setting up the hardware, to the physical arrangement of the classroom and its furniture, to the management of student movement and activities within that setting.

The researcher felt strongly that if she could observe and document what actually transpires in a computer enriched mathematics classroom, other teachers would be encouraged to adopt worthwhile technological changes in their classrooms. It is the challenge of the unknown which inhibits many people from using the computer. The researcher felt that if teachers could have some grasp of what to anticipate and know that others have experienced the same challenges, they would not abandon their endeavors with the computer in frustration. The researcher found from prior personal experience that one must develop a tolerance for unanticipated events when working with computers for teaching and learning purposes.

Educational Significance of the Study

Ragsdale (1988) feels that the school is the place where the future of computers will be predicted and shaped. "It may be that not only is the ultimate effect of computers not yet known, but major effects of their use have not even been anticipated" (p. 14). Papert (1980) describes his microworlds
as incubators in which certain kinds of mathematical thinking can hatch and easily grow. In computer-assisted instruction (CAI), for example, a child acquires a sense of mastery over a powerful piece of technology. Programming and CAI are only two of the applications of computers in the classroom. Other applications are games, simulation programs, and drill and practice tutorials. The potential for education and adventure is mind boggling. The emphasis in the field of computer mathematics education is on promoting better understanding of the mathematics topics. In School Mathematics in the 1990s Howson and Wilson (1986) state that the rapid developments in the applications in mathematics brought about by the computer revolution offer a rich source for experiments and developments with innovative content within a new model. Fey (1984) states that the computer presents new challenges that demand higher-level analytical thinking.

Mathematical concepts new to school mathematics curricula will eventually emerge in school curricula because of the new methods of writing and calculating offered by computers and informatics. Computers are not only a new tool for mathematical research and teaching, but also a source of new areas of educational research. With graphic representations, computer simulations, and symbolic manipulation, interpretation of data will be easier. Students are beginning to be able to exercise processes of exploration and discovery with the infusion of current mathematics software. The author predicts that wide screen displays and new video projection
techniques will open new possibilities for teachers to expand "chalk and talk" techniques. "This in turn will require that teachers relax their control over the ways in which students receive and process information" (Baird, 1986, p. 49).

Driscoll (1988) refers to experts who say that students need to become more involved in doing rather than learning about mathematics. He feels that if the underachieving curriculum (as described in McKnight et al., 1987) is to move beyond the current model of teaching, class periods dominated by lecture and silent student practice can no longer be the rule.

Fey (1984) asserts that the assumptions on which the traditional mathematics curriculum is based will be changed according to the promised and demonstrated capabilities of computers and information technology. Some of the most prominent capabilities are numerical calculations ("number crunching"), symbolic calculations, graphics, databases, and networking. What seems likely to succeed is a sequence of gradual changes (Fey, 1984). This study will observe primarily the use of one piece of software, MET, which does symbolic manipulation and has limited graphic capabilities. In this study only MET's graphing features were observed.

The National Advisory Committee on Mathematical Education (NACOME) (1975) recommended implementing computers in classrooms but with the stipulation that computers must go beyond the traditional computer-assisted instruction or computer-management systems, and that computer literacy must be "hands-on." The present research study is significant in
that it is a case study of what actually occurs in a mathematics classroom while computers are used to teach a particular algebra unit. Frustration results when the will exists to experiment with new teaching methods and tools but the support and experience are lacking. Battista (1988) cautions that if we are not careful, teachers who are naive and negative about the use of computers in mathematics may become frustrated and eventually reject the use of this technology as a tool for teaching and learning. This study will share the experience of two teachers at a similar entry level, that is, the two teachers in the study had little or no prior experience in teaching mathematics using the computer and the selected software.

One of the concerns that has been raised since computers started to find their way into mathematics classrooms is how the curriculum will change if students are to be prepared for the technological age. As computers decrease in cost, their purchase becomes feasible for many school districts. Gawronski (1982) suggests that the potential for curriculum change is increased for two reasons: the relatively low cost of the microcomputer, and as more computers are being purchased for business and personal use, the public will expect the schools to be teaching about their uses. Today, literacy courses are very common, if not present in every secondary school in the country, but integration of computers in the teaching of other subjects is not nearly so widespread.
The opinions in the literature on the topic of curriculum changes are very similar. Taylor (1981) writing on the topic of calculators and computers, supports a total revision of the mathematics curriculum because of the proliferation of computing power. He believes the curriculum needs development in the areas of problem solving, consumer applications, estimation and approximation, and mathematical modeling. More recently, Heid, Sheets, and Matras (1990) identified two challenges: the creation and adoption of a curriculum that utilizes computers and a changing role for students and teachers. The literature often expounds the virtues of the computer and bursts with enthusiasm, but unfortunately it is difficult to find teachers using computers for instruction. There is a lack of empirical research to support the suggestions that have been made. Day (1987) found that the most frequent use of computers has been to reinforce computational skills. This finding contradicts the wish to de-emphasize calculations and the desire to promote applications and problem-solving. Cuban (1986) defends teachers by saying that it is unrealistic to expect them to incorporate technological innovations automatically.

Hatfield (1983) defined instructional computing as "any application of a computer involving direct contact by either the student or the teacher, which serves the goals and functions of instruction" (p. 44). This definition describes the computer environment in which the current research study takes place. The study relates the experiences of both the
teachers and the students involved. The teachers used one computer for demonstration and discussion. The students working alone or in small groups completed the assigned lessons using computers. This study concentrates on the ways in which the teachers may organize their instruction and their classroom, and how they can adapt their use of the computer to the current mathematics curriculum with no implications for curriculum change.

In summary, this research study is significant in that it does not require a new curriculum in order to use the computer as a tool in the mathematics classroom. It is a study of both teacher use and student use of the computer to teach and learn a traditional algebra unit in a novel way. It is a practical study because it describes the slow introduction of the computer, that is, the computer is not used throughout the entire school year in the mathematics course. The teachers have instead decided to try their hand at one particular unit which they suspect is appropriate to be taught and learned with the aid of a computer. Finally, this study is educationally significant because so few teachers are using computers for instruction and because of the scarcity of research in this area. Much of the research into the use of computers in secondary school mathematics focuses on achievement gains in test scores, but little is known about the difficulties involved with adapting teaching and learning styles. Students are accustomed to very traditional classroom settings, and the mere presence of a computer implies a special situation.
Statement of the Problem

The purpose of this study is to discover some of the factors involved when computers are introduced into a traditional mathematics classroom. The Research Advisory Committee of the National Council of Teachers of Mathematics (1990) notes that technology allows the emphasis of different parts of the traditional curriculum and the de-emphasis of others in order to introduce topics new to the curriculum and to reorganize instruction. This study investigates the use of the computer in teaching a single topic, the graphing of functions, that is already part of the Mathematics 11 curriculum.

It is based upon Fey's advice that "...without a precipitous break from tradition, teachers can begin preparing their students for work in the technical environment of the future by modest changes in class activity" (Fey, 1984, p. 93). The researcher was interested in documenting her own experiences as an instructor and observing and describing a colleague in the same setting. The students in the study often worked in pairs, thus the investigator observed how this cooperative arrangement influenced class activity.
**Research Questions**

What salient features emerge in the mathematics classroom when the computer is used to teach a graphing unit?

How do the teachers adapt the use of the computer to the graphing topic and the already established classroom routine and setting?

How do the students adapt to the computer-based learning activities they experience?

What advantages and/or disadvantages do the teachers and students experience when using the computer?

**Method of the Study**

The case study method of inquiry has been chosen for use in this study. Stake (1978) states that the perspective of everyday life is better when reporting to lay audiences. Since one of the goals of this study is to assist practising mathematics teachers to implement computers in their classroom and many of these teachers are inexperienced computer users, the case study method is deemed appropriate.

The research site was a secondary school in Vancouver, British Columbia. Three Mathematics 11 classes were observed over a period of two weeks. The researcher was the teacher in
one of the three classes. The mathematics classroom contained 16 IBM PS/1 computers networked to a fileserver, and it also had a stand-alone computer outfitted with an overhead projection device at the front of the room for demonstration purposes.

The researcher chose to observe the Mathematics 11 classes while they were studying the unit on graphing of functions, which is chapters 6 and 7 in their textbook. In another teacher's classes, the researcher was a passive observer while the teacher presented his lesson, and was a participant observer when the students worked on their assigned tasks at the computer. The researcher took field notes as she observed passively and as she circulated around the classroom chatting with and observing the students. The field notes were typed up each evening to produce a thorough description of the activities during the mathematics classes. The researcher conducted informal interviews with the teacher on a daily basis and recorded his comments in point form in the field notes. These interviews were also typed from point form into a more detailed account.

The researcher also used her own Mathematics 11 class for research purposes. She took field notes as the students were working at the computer on their assignments. Each evening these notes were typed in greater detail than the point form taken on site. As well, the researcher kept a journal of her perceptions of her own teaching and her personal experience of teaching a lesson with the aid of a computer.
At the beginning of the study, the researcher explained to the students her dual role as teacher and investigator. The students were given the option of not participating in the study by declining to answer the researcher's queries of them while she circulated around the room and chatted with them. The method of the study will be described in greater detail in Chapter 3.

Limitations of the Study

The research study was limited to one pre-selected research site. As well, at this one site, one particular piece of software was used predominantly and at one grade level. As explained earlier, this site was chosen because of the joint study into the use of the MET software. This was a very convenient situation in that under the sponsorship of the IBM company, the availability of hardware, software, and service technicians would greatly encourage and assist in the implementation of the computer in the mathematics classrooms.

The study was limited to two teachers, one being the author. These two teachers were teaching Mathematics 11 in the computer laboratory at the time of the study. This facilitated access to the computers.

This study is also limited to one instructional unit in Mathematics 11, the graphing of functions. This unit was chosen because the researcher had some previous experience using the computer to teach graphing techniques in
mathematics. In the previous school year, the other teacher in the study had collaborated with the district’s mathematics consultant in developing some lesson materials, which were guided explorations using the MET software. However, the opportunity to test and refine those materials was not available prior to the study.
CHAPTER 2
REVIEW OF THE LITERATURE

This study is concerned with the process of introducing computers into the mathematics classroom. The literature review focuses on the process of integration and other related issues. The Research Advisory Committee of the National Council of Teachers of Mathematics report on mathematics education reform (1990) states that technology allows one to emphasize different parts of the traditional curriculum and de-emphasize others, to introduce topics new to the curriculum, and to reorganize instruction. The current literature not only focuses on the use of technology in the classroom, but calls for research into the ways teachers choose to reorganize their instruction and the curriculum. At present, the use of computers in the mathematics classroom is an option for teachers, and the uses vary from computer-assisted instruction to games. The literature review is divided into three sections: (a) educational innovation and the challenges of the changing mathematics curriculum, (b) the effects of computers on classroom instruction in general, and (c) the effects of computers in mathematics classrooms.
Educational Innovation and the Challenges of the Changing Mathematics Curriculum

Educational innovation is a broad reaching term which describes classroom methods that have not been part of a traditional educational setting. These innovations are not necessarily completely new, but are now more widely accepted in educational communities. Computers are a good example of an innovation that is more accepted now than it was in earlier years in that computers have been used in schools since the 1970s even though their widespread use has not been feasible because of the high cost of the hardware and the poor performance of the software.

The discussion of the use of computers as an educational innovation in mathematics is presented in six sections: (a) potential of computers in the mathematics classroom, (b) new and traditional programs, (c) implications for teacher training, (d) changing roles for teachers and students, (e) cooperative learning, and (f) teacher decision-making.

Potential of Computers in the Mathematics Classroom

The potential of computers in the classroom is exciting and at times overwhelming, but "sometimes innovations are rationally solid on the basis of sound theory and principles, but they turn out not to be translatable into practice with the resources at the disposal of the teachers" (Fullan, 1991,
Fullan presents a very cautious view of computer use in the classroom and warns that even where good intentions exist, the gap between the benefits promised and those received remains very wide. Hofmeister (1984) shares a similar view, "... [A]s our cultural experience with television indicates, great potential does not guarantee wise use" (p. 4).

Mathematics classrooms were among the first to introduce computers because many mathematics teachers had computer programming experience. The use of computers in mathematics classes from the late 1970s through the early 1980s included the teaching of programming skills in languages such as Fortran and BASIC and it also included drill and practice programs. These applications do not illustrate the potential of present day computing.

We must remember the fate of drill and practice programmed learning and not make the same mistakes again. ... If we develop lessons whereby data can illustrate, motivate, and help students remember the traditional concepts of algebra, then we will have tapped the computer's resources (Krist, 1981, p. 55).

The potential of the computer in mathematics education is in its ability to motivate students to think about the presentations and to ask questions in order to sharpen their problem solving abilities.
New and Traditional Programs

The comparison of new and traditional programs goes beyond the introduction of new tools such as computers. The introduction of a new program must also consider new or revised teaching techniques, approaches, materials, and beliefs. Heid, Sheets, and Matras (1990) discuss how evaluation techniques, time allocation, and classroom activities change in a computer enhanced curriculum as compared to the traditional curriculum.

The three factors which affect the evaluation techniques are that the evaluation of a wider range of mathematical abilities will take place, student learning is more visible in a computer enriched problem solving environment, and new evaluation objectives must be developed. Teachers will have to consider assigning group marks as well as individual marks. The teacher must keep in mind that some students will have computers at home and they may also have access to the software so that they may develop an unfair advantage at testing time in that they will have had more time to practice the computer related tasks.

In discussing time allocation, Heid, Sheets, and Matras (1990) state that it appears that the length and content of class discussions is unpredictable. The usual formula of introduction/class discussion/guided practice does not work when applied in a computer laboratory. If the traditional formula is used, there is not enough time for computer
activities, and students are forced to try and use the computers at lunch time or after school; thus those students with computers at home would definitely have an advantage. Geisert and Futrell (1990) also discuss the time factor noting that "the cost-effectiveness of a computer hinges on how many hours a day it helps in the teaching/learning process" (p. 173). Also with regard to time allocation, absentees and slower paced students are difficult to deal with in a laboratory setting. Heid, Sheets, and Matras (1990) suggest that an alternative is multi-day goals rather than having to finish an assignment in a single day.

The classroom lessons in the computer-based program must be developed so that they interface with the computer activities and with the prescribed textbook. For most students, the textbook is the only resource, other than the notes they take in class, that they will be able to take home with them. The lessons must include not only the subject matter but software and hardware features and problem-solving strategies as well. In a traditional classroom, lesson activities are centered on classroom notes and the textbook, while in a computer-based classroom lesson activities must also take into account features of the software, hardware, and related problem-solving strategies.
Implications for Teacher Training

In many settings teachers are thrust into computer enriched classrooms with little or no prior training and with little opportunity to have completed lesson planning or goal setting with respect to computer use. Maddux (1988) describes what he calls the "Everest Syndrome" which refers to educators who use computers simply because they are there. People who succumb to this syndrome believe that children will benefit from computers merely by being exposed to them. "In schools, this may result in computer implementations that overemphasize what hardware can be made to do, rather than what children using computers can be empowered to do" (Maddux, 1988, p. 5).

Empowerment is supported by Munday, Windham, and Stamper (1991) who call for pre-service teacher preparation. "Teachers must be given the training needed to empower not only themselves but also their students through technology" (p. 31). Flake (1990) spent four years interviewing and documenting the experiences of pre-service secondary mathematics teachers and then compared the attitudes of the first year's group and the last year's group. In their first year these student teachers were resistant to using computers. They did not see teachers out in the field using computers in their classrooms. These pre-service teachers had an opportunity over the course of the four years to use various pieces of mathematics software and slowly the computers
acquired meaning for them as an instructional tool. Flake found that in order for the computers to achieve meaning the student teachers needed to: a) use the computers often enough so that they reached a level of immersion, b) experience learning in a meaningful way, using computers in this case to improve their skills in mathematical proofs, and c) work with other students and observe them learning with the computer. Thus teachers require pre-service as well as in-service training. The training will raise their confidence and enlighten them to the potential of computers. The training will help teachers assume new roles and help them to assist their students to adopt new roles.

**Changing Roles for Teachers and Students**

As computers are integrated in mathematics classrooms, the roles of teachers and students are apt to change. Teachers must learn to act as facilitators of cooperative learning as well as being learners, and teachers must learn to become effective catalysts for student-directed learning. Corbitt (1985) provides cautious advice in stating that teachers "must recognize that individualized technology-enhanced learning is not synonymous with independent study" (p. 248) and suggests that teachers will become learners. When asked a question by a student in a computer setting, the teacher, in Corbitt’s opinion, must be prepared to answer, "I don’t know, yet." In using the computer for exploration, the
student may pose a whole range of questions that the teacher has not yet considered.

Heid, Sheets, and Matras (1990) suggest that teachers must become technical assistants, collaborators, and facilitators. These teachers will now be faced with a wider range of student problems to solve. Many computer settings are laboratory settings where students must share computer work stations; thus the students will have to learn to work together in these laboratory settings which will be different from science laboratory settings, for example. This implies that the students too must become collaborators. They must accept greater responsibility for their own learning, and they must find new ways of assessing their understanding. The students will be forced to think about their findings because answers to computer activities cannot be found at the back of a textbook.

Computer based learning (CBL), which is the use of computers to enhance learning, is problematic. According to Olson (1988), when teachers supervise CBL, their influence is challenged by such factors as looser class arrangements and more disruptions. Teachers must diagnose and remedy problems quickly, and this is often not feasible. As well, in CBL the students ask many unanticipated questions and teachers are required to be flexible in their responses. Thus, Olson feels that computers must fit into classroom routines if they are to be useful to teachers.
Cooperative Learning

As shown in the previous discussion, the teacher’s role changes with the introduction of computers into the classroom to include that of a facilitator of cooperative learning. The students must learn to work together in groups of two or more in order to share computer facilities. As well, task related discussions among groups of cooperating students will often guide the learning. Heid, Sheets, and Matras (1990) acknowledge the benefits of cooperative learning and state that the teacher needs to be able to assess the work of the students at the computer stations and must be able to encourage successful group arrangements.

Lampert (1985) realizes that a clear distinction between tasks related to social organization and tasks related to instruction is unachievable. It is not possible in schools to separate social problems from subject-matter knowledge. In the computer laboratory/classroom this is very true; the computer classroom tends to be a very social environment because students must usually share equipment; they work in close proximity to each other; and they are moving from desks to computer stations or from classroom to laboratory. Thus, in order to apply cooperative learning techniques in the classroom, the innovative teacher is challenged to plan computer activities in conjunction with cooperative learning.
Teacher Decision-making

The successful use of a computer in the classroom depends on varied teacher decisions and many planning aspects. The introduction of computers broadens the range of decisions to be made, the first decision being the commitment to actually use the computer. There is no global authority on how computers should or can be used in the classroom, therefore teachers are obliged to exercise more responsibility for what goes on in the classroom. "The teacher, responding to the needs of the pupils, appears to be able to do almost anything that professional judgement deems correct" (Eggliston, 1979, p. 2). Some of the problems that arise when attempting to use computers in the traditional classroom are hardware malfunctioning, equal time allocation for all students at the computer, and the realization that the lesson could have been better taught using traditional methods. Lampert (1985) indicates that a great deal of work is required to manage these problems.

Some further opinions are offered on the obligations teachers have to make critical decisions (Corbitt, 1985; Ediger, 1988). Corbitt (1985) discusses the need for teachers to make informed decisions about questions that relate to certain aspects of the mathematics curriculum, such as where and how to use technology, how to use computer-managed instruction, and how to use visual displays to make the
transition from concrete experience to abstract mathematical ideas.

Ediger (1988) perceives that administrators and teachers need to study the philosophical implications involved in utilizing modern technology. There must be relevant purposes involved when using the computer in the classroom. As shown earlier (Maddux, 1988), many teachers in the field have not had pre-service training in the classroom use of computers, and they do not have the luxury of time to study the philosophical implications. The first decision required of the teacher is that of actually deciding to use the computer for instructional purposes. Once that decision has been made, many other decisions follow in the course of actually proceeding with the implementation.

The decision-making techniques as described in the literature (Eggliston, 1979; Corbitt, 1985; Lampert, 1985; Lampert, 1986; Russell and Munby, 1991), evolve over time through direct experience. "The teacher is not only confronting choices about how to use means to arrive at desired ends, but continuously redefining what those ends can be" (Lampert, 1986, p. 82). Teachers often make spur of the moment decisions and continuously weigh changing evidence. Many of the dilemmas in a computer setting cannot be anticipated and teachers are faced with making the decision to respond to the problem with a solution or to defer a solution until they have had time to ponder a solution further.
Reframing is an important process for guiding the decision-making process. Russell and Munby (1991) describe the process of reframing which "involves 'seeing' or 'hearing' differently, so the process of perception is a unified process in which observation is interpretive" (p. 165). Reframing reveals new meanings in theory and new strategies for practice. Teachers learn from experience and this experience naturally leads to reframing.

Shavelson, Winkler, Stasz, and Feibel (1985) described a study where teachers have made decisions on how to use microcomputers in their classrooms based on their own personal backgrounds. The study will be described in detail because of its similarities to the current research study; it is a case study, the computers are used in mathematics, and the teachers have decided to use computers because of their personal interests. Their research was a naturalistic field study of public school teachers who were nominated as "successful" in their microcomputer based mathematics or science teaching. Shavelson et al. adopted a theoretical framework referred to as teacher decision-making. Teachers' plans are the major focus of this conceptualization. The process of formulating and evaluating plans involves four steps:

1. Integrating information about the students, subject matter, and teaching environments.
2. Monitoring the on-going activities.
3. Maintaining the flow of activities or activating a routine for handling unplanned events.
4. Evaluating outcomes of instruction in order to improve teaching.

The data collected in the study were obtained from personal semi-structured interviews with 40 elementary and 20 secondary teachers. The observational and interview notes were transferred onto an extensive questionnaire. Sixteen variables were identified as ways of characterizing teachers' methods for integrating technology in the classroom. These 16 variables were then clustered into four groups: those that reflected the teacher's instructional goals; variables that highlighted features of the curriculum; those that indexed instructional activities; and variables which indicated some form of evaluation or perception of success. Six of the variables characterizing instructional use were then utilized in a cluster analysis of the data.

The researchers found that the teachers varied greatly with respect to their goals, with respect to the degree to which they used microcomputers instructionally and integrated them with other classroom activities, and with the extent to which they varied their mode of instruction. Another finding was that all teachers were similar in that they did not use the computer to motivate the students or for management purposes. All the teachers attempted to allocate equal computer time to each student, approximately one hour per week. As well, most teachers used drill and practice, five of the 60 teachers using it exclusively. Teachers with a science background tended to use the drill and practice activities,
whereas teachers with substantial software knowledge tended to use a variety of methods. The researchers also found that minority and low-ability students received mainly drill and practice.

This study showed that the patterns of microcomputer use varied among the teachers from enrichment, to exclusively drill and practice, to an orchestration of various methods. Although the teachers were chosen for the study because they were nominated as successful in microcomputer use, successful in this context can mean that they simply had a microcomputer available for their use and accessed it when they could. The authors admit that there was not a large group to choose from. It is interesting to note that the researchers found that district and school policies did not influence use; rather, patterns of use were related to differences in subject-matter backgrounds of the teachers and the composition of their classrooms.

Summary

The literature concerning educational innovation and the changing mathematics curriculum presents many challenges to teachers and to students. The challenges include changing roles, new cooperative learning settings, and an emphasis on thinking and problem solving skills. Teachers will have to make decisions on how they will adapt the curriculum and develop new curricula to usher in the innovative educational
methods. Teachers will also realize the need for new resources.

The literature on decision-making has shown that teachers constantly have to make decisions, sometimes on the spur of the moment, and that they have to accept responsibility for those decisions and live with the consequences. Problem-solving involves the skill of making informed decisions after weighing the choices. Reform depends on the teachers being critical and on their being able to reframe their experiences and evaluate the alternatives. Computer use allows the teachers and the students to experiment with new techniques and to experience education in new ways. The next section will discuss some of the literature dealing with the effects of computers on classroom instruction in general.

The Effects of Computers on Classroom Instruction In General

This section of the literature review will concentrate on the use of computers in classrooms in general, not specifically mathematics classrooms. An emphasis will placed on case studies. Trollip and Alessi (1988) cite six circumstances in which the computer will improve the learning environment: a) When the material is difficult to teach using other media, for example, graphing of complicated equations; b) when practice is needed; c) when there are safety factors, for example, a science experiment; d) when costs are high, for example, using simulations for training; e) when motivation is
required; and f) when there are logistical difficulties, for example, studying whale migration. It has been shown (Heid, Sheets & Matras, 1990) that the use of computer technology promotes small group activities. The discussion will begin by presenting further claims (Hawkins & Sheingold, 1986; Male, 1990; Demana & Waits, 1990) regarding the benefits of cooperative learning and research supporting those claims (Feldman, Fish, Friend, & Bastone, 1991; Johnson, Johnson, & Stanne, 1986).

**Cooperative Learning**

Cooperative group work is often necessary in a computer-based learning environment because of the small number of available computers. Cooperative learning requires that students share equipment and collaborate in solving problems or completing assigned tasks. Hawkins and Sheingold's (1986) research noted that two kinds of changes were observed in a computer-based learning environment: the ways in which teachers interact with students in learning situations and the increasing emphasis on students' collaborative learning. They point out that group work raises questions of how to monitor the progress of individual students and when to intervene in student-based activities.

Feldman, Fish, Friend, and Bastone (1991) found that students paired at the computer demonstrated enhanced task-oriented social behaviours. They surmised that this could be
because there was less reliance on instructions from the teacher. They felt that there may be more social assistance among peers and more self-reliant behaviour because students get so many opportunities to work together when using the computer. Gender was not a factor in any of the social behaviours observed.

Johnson, Johnson, and Stanne (1986) investigated the impact of computer-assisted cooperative, competitive, and individualistic learning situations on achievement, task-related oral interaction among students, relationships among students, and attitudes towards computers. In general, the students working in groups, in this case computer groups, completed more worksheets, correctly answered more questions, scored higher on the final exam, accumulated significantly more gold \(F(2,64) = 28.72, p<0.01\), expressed more task-related statements (more to other students, less to the teacher), and nominated more females as future work partners than the students working in the other two learning situations. The students in the cooperative and competitive groups liked computers more than the students in the individualistic groups. The results of this study show the positive effects of the cooperative process, once again, a strong statement in support of cooperative learning.

Male (1990) outlines five components required for a successful computer lesson:

1. Assignment to teams and team preparation.
2. Establishing positive interdependence.
3. Direct teaching of social skills.
4. Ensuring individual accountability.
5. Processing.

The first component, team assignment, ensures a heterogeneous mix. Male suggests assigning a group grade to provide for students depending on each other. There must be a reason for students to work together; otherwise they will work individually. Some of the various social roles suggested are keyboarder, reporter, praiser, checker, summarizer, encourager, and timekeeper. To ensure individual accountability, individual quizzes or collecting work at random should be attempted. The processing component involves addressing issues about how well the groups are functioning. These five components are part of the general cooperative learning model and are not specifically designed for computer lessons. Demana and Waits (1990) support Male's model with their finding that the greatest benefits come from interactive technology that is under student and teacher control, that promotes exploration, and that enables generalization.

The Integration of Computers in Classrooms

The integration of computers in classrooms is by no means a simple process. The literature on the integration process highlights promises, concerns, successes and failures. Hill, Manzo, Liberman, York, Nichols, and Morgan (1988) make a plea for computer integration. They see the computer as a "non-
threatening, non-judgemental device which stimulates minds and whets perceptions" (p. 48). Maddux (1989) on the other hand makes a plea for caution. He believes that the calls for integration are premature, though they are appropriate for the long term.

Vannatta (1981) describes the evolution of computers for instructional purposes in the Indianapolis Public Schools (IPS). The three goals of the IPS were to use computers for teaching computer literacy, for practice and reinforcement of mathematics skills, and for computer programming for interested students. Although according to today's standards these goals are not considered computer integration, Vannatta identified four areas of concern which are certainly prevalent today. These concerns will be presented in detail since they relate closely to many of the salient features found in the current research study.

The first concern was with regard to administrative difficulties. An administrator would have to deal with training teachers, scheduling, providing instruction regarding the use of the facilities, and coping with skepticism and passivity on the part of the staff. It was found that teacher training, discussed earlier as one of the implications of educational innovation and one of the administrative duties mentioned above, was a second area for concern. Teachers had received poor college training in the use of computers, so summer courses were arranged as well as on-site training. The problem with on-site training was that the qualified trainers
were often the computer administrators. Those people were usually over-worked, which is understandable, considering all their responsibilities.

The third area of concern was the location of the computers. They were situated in either classrooms, laboratories, or media rooms. In the classroom situation, the classrooms were usually mathematics classrooms. Though they provided immediate availability, students were denied access while other classes were in session. Security in this situation was good as long as the teacher kept the door locked. The laboratory provided a fixed accessible location, although an aide was required in order to provide security and access to the students. The media center tended to encourage broader use, but classroom demonstrations were more difficult to arrange.

Service and maintenance were the fourth area of concern. There was some controversy about service contracts versus on-call service. In-house service is the ideal solution thus eliminating the dispute over who pays for the service.

Five case studies will highlight other aspects of the integration of computers in classrooms (Olson, 1986; Watson, 1990; Plomp, Pelgrum, & Steerneman, 1990; Sheingold, Kane, & Endreweit, 1983; Bresler & Walker, 1990).

Olson (1986) describes the "teach yourself" routine as part of "doing" computers as a subject. In the cases he studied, teachers were experimenting with a new subject and with new ways of teaching that subject within the existing
constraints of the curriculum and available resources. The students would take turns using the computer while the teacher maintained whole class instruction. There was only one computer, and it was part of the classroom reward structure.

It is common for teachers to do two things at once but in this case they found it difficult to teach two classes at the same time. The "teach yourself" routine works well in other contexts, for example, in library situations or when each student has a work station. In the case of the stand-alone computer, the programming was difficult and not user-friendly thus the students needed help constantly. The students posed management problems that could not be dealt with quickly. Their peers did not assist; they just fixed the problem. Even though the routine did not work as well as expected, the teachers were going to continue with this way of teaching.

The teachers perceived using the computer as being modern and an expression of what kind of teacher they were. They enjoyed observing the students' pleasure of having a computer in the room. Olson says that "as teachers work their way through the expressive dimensions of their task, it is likely that instrumental issues will receive more attention" (Olson, 1986, p. 138). The teachers obviously valued the computer as a symbol to be used expressively by them. Olson states that the teachers felt that they could ignore the minor difficulties in achieving computer literacy for the short term because they were not as important as the expressive process.
Watson (1990) conducted a case study of 11 classrooms and teachers. Four of the classes used one microcomputer, one class used two, and six classes used eight to ten machines. Six of the 11 classes took place in specialized computer rooms. The levels of activity and interest were observed, and teachers and pupils reported that there was not enough time to complete the exercises. Watson supports a preference for using stand-alone computers in subject based classrooms. "It is possible that the establishment of specialist computer rooms will threaten the very innovations that they are meant to herald" (p. 33). The shift from regular classrooms to a computer room proved to be a negative factor and did not encourage a sense of integration. Though Watson sees the stand-alone system as an easily managed resource, he does not anticipate the difficulties that Olson (1986) describes in his study.

Plomp, Pelgrum, and Steerneman (1990) conducted a case study of computer use in three schools and followed up with a telephone survey to validate their findings. They selected three junior secondary schools which could be considered as leading schools. To correct for possible bias, they followed up their case study with a telephone survey among a sample of leading schools. Using interviews and questionnaires, they collected information concerning computer facilities and uses in schools, and the factors influencing implementation.

The data collected in the study included factors favouring implementation and factors constraining computer
use. Some of the implementation factors reported by principals and computer coordinators were reason to start using computers, policy, facilities, organization, training and support. The data from the telephone survey (16 schools were surveyed), identified the factors constraining computer use. Some of the factors were lack of hardware and software, poor quality software, too few computer using teachers, and lack of support and inservice training. Though many computer activities were taking place, "real" integration was not taking place. The leading schools did not progress much past the grass roots development. "One may suspect that an important part of the disappointments when introducing computers in schools is due to paying insufficient attention to factors which play a crucial role in implementing educational change" (Plomp, Pelgrum, & Steerneman, 1990, p. 159).

In the case study conducted by Sheingold, Kane, and Endreweit (1983) the emphasis was on the social and political contexts that influenced the classrooms as well as what happened in them. They wanted to identify problems and issues as well as generate an empirically based research agenda. Fifty-one observations were made across three sites. In the elementary schools, the computers were found in media rooms, in resource centers, and in hallways. These locations avoided the challenge of integrating computers in classrooms and curricula. The researchers found that each school assimilated the microcomputers to their own goals, needs, and ways of
operating. The social skills were relatively obvious, but although the teachers felt that there were gains in social skills, no one seemed to know what the children were learning from the computer interactive experiences. Perhaps the computers were meeting the expressive needs of the teachers as found by Olson (1986). Bresler and Walker (1990) also address the issue of expressive teaching acts, noting that "[e]ven when an innovation meets people's expressed needs, it may still not succeed unless it fits in with the patterns by which they run their lives as students and teachers" (p. 71).

Integration of computers in classrooms requires changes in actual uses of computers, in teaching approaches, and in beliefs. Bresler and Walker (1990) found an ideal setting for computer integration. They present the case study of an introductory music class at a private university in a high-tech industrial community. They collected their data over a ten week period. Seventeen students were observed using computers over approximately 13 sessions. They then conducted follow-up interviews with 14 of the computer users, six non-users, and an instructor and a teaching assistant.

The setting proved to be ideal because it offered adequate hardware and appropriate software; there was a close match between the content of the software and the goals of the course; there was a commitment from the institution to support the course; the instructor supported the use of computers and knew how to use them for the subject (music) of instruction; and the students were interested. Despite these favourable
aspects, the attempt to integrate the computer in this music course (ear-training/theory) failed. Bresler and Walker (1990) outline some of the barriers in terms of the instructor, the students, and the program designers.

The researchers fault the instructor and the factors which relate directly to the instructor for the lack of success. The instructor did not clearly state the goals of the course. He did not reconsider the non-computer aspects of the course in order to implement the computer component. Evaluation was based on pencil and paper tests. In terms of the pedagogical elements, the instructor showed a strong preference for being the center of attention. He would have had to relinquish his control by allowing students to move to the computers. He considered it a chore to ensure that all students worked at the computer. While the computer software was student controlled, the students were passive participants in the music theory class. None of the other teachers used computers for instruction, thus the instructor had no peer support, and there was a lack of external incentives for the teacher to volunteer extracurricular time to develop the computer course. "As mature adults with responsibilities for jobs and families, teachers have little free time for learning a new system. Efforts should be made to relieve mature individuals from competing responsibilities and to provide an extended period for mastering the new technology" (Bresler and Walker, 1990, p. 71).
The students found the software boring and repetitive and simply not a lot of fun. Since they had to sign up for computer time, and the tests were based on the text materials anyway, they did not spend their voluntary time at the computer. The program designers did not give explicit guidance on how integration should be done. The program manual did not include tutorial information nor did it state explicit goals. This case study once again underscores the need to rethink and reorganize instruction as it relates to the curriculum, and since the teachers are ultimately responsible for the successes or failures, they must be given ample opportunity to develop materials and to reshape their traditional role.

Summary

Successes and failures to integrate computers in a classroom routine have been documented in the literature. The research outlines some of the variables and features of computer use in classrooms which have implications for practising teachers. The major role that cooperative learning serves in computer integrated classrooms is noteworthy. The current case study provides further insights into many of the same features presented.
The Effects of Computers in Mathematics Classrooms

The recent literature concerning the effects of computers in mathematics classrooms contains mostly suggestions about the possibilities of computer use and relies on predictions rather than facts. The studies which have been conducted are in many ways contrived in that they portray specialized situations, rather than realistic classroom situations. For example, Ernest (1988b) used a small group of only 12 students, McCoy's (1991) subjects consisted of high ability students, Martin (1987) conducted her research at the Bank Street Institute, a school designed specifically for research purposes, and the school in the study by Zehavi (1988) bought computers with substantial support from the parents, thus there was political pressure to use them and the teachers had to ensure that all students had equal access to them. The positive results obtained in these studies were mostly in respect to students' attitudes and motivation.

Like the more general studies, the literature regarding computer integration in mathematics classrooms at the secondary and college levels also highlights contributing factors such as computer use and availability, achievement and attitude, and cooperative learning. Once again, the group work model is seen as an exemplar used in most computer integration situations.
Computer Use and Availability

Computer use varies from situation to situation, based on availability and accessibility factors. As well, the teacher's personal experience with using computers will affect their use. "Using computer-augmented instruction is useful in situations in which there are time-consuming activities which are not central to the objective of the lesson but are necessary for attaining that objective" (Bassler, 1986, p. 186).

Tall (1987) presents an opposing point of view. He reports on the findings of the Teaching Sub-committee of the Mathematical Association in the United Kingdom. He found that those teachers who used computers more often than others felt inhibited by the difficulties in setting up the computers, the time it took the students to start using the software in group work, and the general difficulties of administering its use. In one school cited in the report, where the computers were networked, although there were more computers and the students did not have to line up to use them, there were new skills the teacher had to use to manage the networked system. The curriculum had to be planned so that the time that was allocated for use of the computer room was put to its best advantage. Often the system was used so infrequently that the teachers forgot the technical skills and lost confidence. Thus they never developed the expertise to make them want to use the system more often.
These are useful suggestions offered by Tall (1987) and serve as a reference point when considering the studies on computer use and availability. The computer tasks must be planned so that the students get on with their work right away and the teacher is allowed the freedom to move around the room to observe and give individual attention. It appears that those teachers who are computer literate are using the computers successfully. It is these teachers who must help others to gain confidence.

The software programs used in Damarin, Dziak, Stull, and Whiteman's (1988) study were integrated within the regular mathematics classroom by being placed on three computers in the classroom. Students were allowed to use the computers as an alternative to beginning the next assignment or instead of asking the teacher for help during worktime at the end of the class. The assumption implicit in the study was that the computer-based instruction, in this case drill and practice in estimation skills, could be added to the classroom with minimum disruption to the regular routines.

Over the eight week period, students were rotated three to a computer, such that each student received four hours of computer-based instruction. With this approach, the teacher could continue to help individual students with ongoing curriculum and use the computer to reinforce estimation skills, not a curriculum topic, while not sacrificing time from current work.
Martin (1987) looked at district procedures and how they influence classroom change. The first phase of her research focused on technology and how it was seen to influence what was done in the classrooms, and what in turn influenced its use. The 16 teachers of grades four, five, and six and ten staff developers were given a week long training session in using the Voyage of the Mimi series. The teachers were pleased with the software and lesson materials because they allowed an entry point for everyone. The teachers' efforts were highly reinforced by student attentiveness.

Martin (1987) considered the demands on the teachers, such as utilizing new technologies in new ways and approaching subject matter in new contexts, as manageable, even revitalizing. The microcomputer was for all the teachers a novel teaching tool and an unfamiliar medium. Though it was not evident in the study, Martin suspects that as teachers become more comfortable with the materials they will become more open-ended in their lesson arrangements.

McGivney (1990) describes the use of computers in an introductory college course catering to students who had had a negative experience with mathematics in the past. There were 27 students in the course, and they used a computer laboratory situated in a room different from the classroom. The instructor saw the need for interesting laboratory problems and found the writing of such material enjoyable but very time consuming. He enlisted the aid of a laboratory assistant in order to manage the course. In general, the student
evaluations of the course were positive, but some criticisms were: a) crowded laboratories, b) lack of help in the laboratory outside of class time, c) the need for software demonstrations before the laboratory sessions, and d) the absence of answers to the assignment. Managing classroom time, resources, and activities is a concern of many teachers, as it was for the teacher in McGivney's study. Unfortunately, this aspect of computer use is not emphasized in the literature.

Achievement and Attitudes

Many of the studies of computer use in mathematics classrooms are quantitative and have investigated achievement and attitude. In the Zehavi (1988) study, where students were ensured equal access to the computers, the software was developed to build on students’ understanding of points and their corresponding coordinates. The students had to identify which points fit a given rule, or which rule fits a given point. The seventh grade experimental group of 78 students demonstrated intuitive understanding of how to solve linear equations and inequalities. The retention study done eight months later, when the students were in the eighth grade, showed significant positive results (p<0.05).

Short term positive results were obtained by Tall and Thomas (1991). They found that computer experiences resulted in significant improvement in understanding in the short and
medium term, that is up to 18 months, but if the experiences were not continued, their effects diminished in the face of the overwhelming influences of more recent experiences. They also found evidence among students in the experimental group of versatile thinking where "global, holistic processing complements local, sequential processing" (p. 125). In individual interviews, these students were able to offer reasons for their thinking, to discuss processes without having first to carry them out, and to take a global view of the problem rather than relying on processes.

Ganguli (1990) investigated the use of the computer, at the college level, essentially as an electronic chalkboard. He found that the students in the experimental group were better able to form pictures of algebraic functions after the lesson was taught with computers; thus they performed significantly better on the comprehensive final exam, although there were no significant gains with testing in the short term.

Many of the studies in the literature on computer use in mathematics take place either at the elementary level or the college level. This may be due to the constraints of high school schedules. For example, MacGregor, Shapiro, and Niemier (1988) conducted a study at the college level where students generally received four hours per week of classroom instruction in elementary algebra and an additional one hour in the computer laboratory. Their study showed positive attitudes with no significant differences in terms of
achievement as measured by test scores. High school students typically receive three hours per week of classroom instruction.

High ability students were used as the experimental group in the study conducted by McCoy (1991). The students used a computer program called the Geometric Supposer once every two weeks. They worked in small groups on activities from the manual or adapted from their textbook. The group which received the Supposer treatment scored significantly higher on the final exam than students who did not use the Geometric Supposer computer program. The difference in posttest achievement scores was found in application and higher order questions. There was no significant difference on lower level knowledge and comprehension questions.

Using a small group of only 12 students, Ernest (1988b) found that the gain scores were highest with respect to motivation. He predicted that for a full class, the demands on the teacher would increase four fold.

In researching mathematical problem solving skills, Ernest (1988a) used two groups, not assigned randomly, a computer room group and a classroom group. The computer room group worked in pairs at computers; the classroom group sat close to a single computer and watched a teacher demonstration. He found that the two CAI modes seemed to have no significant overall effect on student achievement. In fact, the modes seemed to be ineffective.

48
Dalton and Hannafin (1988) studied the use of computers to deliver remediation in computation skills. The subjects were given the "revised math attitude scale," a 20 item Likert type survey. It was found that students performed best when the delivery system employed for the remediation was different from the system used for the initial instruction. The results of their study suggest that traditional and computer-based delivery have valuable roles in supporting instruction but they are most valuable when complementing each other. Dalton and Hannafin claim that the issue in computer-assisted instruction is how to vary instructional methods and technologies meaningfully and effectively.

Cooperative Learning

The next two studies conclude the review of the literature. They are relevant to the current research study in that they are also case studies exploring the mathematical topic of functions in a computer laboratory environment. Sheets and Heid (1990) observed teachers and students using an experimental curriculum called Algebra with Computers. This curriculum focused on the concept of functions and explored ways in which functions arise naturally in a variety of real-world settings. They discuss the group work that emerged during the implementation of this mathematics curriculum.

Most of the classes were held in a standard classroom with the occasional use of a microcomputer and a large screen
monitor. The teachers and students also had access to a laboratory with 15 microcomputers. The students were given a problem (to plan a talent show) and an outline of the tasks to be completed, but they were not given any guidelines on how to organize themselves into groups in the laboratory. In the early stages of the laboratory experiences, the teachers functioned as technical assistants and as task masters. The students seemed to choose their roles based on differences in their personal styles. Initially, they paid more attention to producing an individual report rather than a group report and hurriedly input the data.

The students did not hurry through the follow-up activities. They deliberated and shifted their attention to the mathematical ideas. It was noted by the observers that the stronger students often offered assistance to the weaker ones. The students pooled resources by forming teams from the computer pairs. "The computer labs provided a learning environment where engaging in pair and small-group decision making and utilizing fellow students as legitimate resources for learning increasingly became the order of the day" (Sheets & Heid, 1990, p. 274). Groups seemed to share strategies, and each pair remained on task until the end of the class period.

The teachers found it effective to move from group to group making problem-solving hints they picked up from other groups. The teachers shared strategies with students who were apparently having difficulty in identifying the function rules. Sheets and Heid (1990) saw this computer environment
as a promising move toward a classroom environment fostering more student initiative, responsibility, and commitment to task accomplishment. They also noted that the nature of the software, the type of problems assigned, and the development of concepts prior to the computer laboratory work all contributed to successful small-group environments. The Algebra with Computers curriculum illustrates the evolution of group work, the unfolding of individual work styles, and the shift in teacher and student roles.

Lynch, Fischer, and Green (1989) developed and field-tested curricular materials to achieve three basic objectives: (a) to develop students' understanding of concepts and abilities to solve problems before they master conventional symbol-manipulation techniques, (b) to make the concepts of function and relation the central organizing themes for theory, problem-solving, and techniques in algebra, and (c) to give students realistic applications. The authors found that "finding the right combination of challenge and support for students in laboratory sessions is not an easy task" (p. 691). They call for new classroom organization and new student-teacher interaction patterns.

The lessons consisted of an introduction, an exploration, and a homework assignment. Each significant idea was usually introduced in the context of a realistic situation. The introduction was then followed by related explorations in small groups. The homework assignments focused on analysis and interpretation of the function tables, graphs, rules, or
other results of the computer activities. They used a variety of software to complement the textbook, and the use of computers was required on most tests and quizzes. These students were required to read and write in mathematics class. There were two components to the class; students worked alone on the non-computer component and in the small groups on the computer component. The laboratory was across the hall from the classroom, so the teacher monitored both rooms by moving from one to another.

In the first year of the project, the teachers had difficulty asking good probing questions. The class period often ended before closure on an idea had been achieved. The researchers also observed that the discussions increased the verbal facility of students. The students gradually became more flexible and willing to take risks in problem-solving situations. "The design and management of an effective laboratory lesson is clearly a valuable skill the mathematics teachers should acquire" (Lynch, Fischer, & Green, 1989, p. 692). This computer-intensive algebra curriculum illustrates new ways of organizing, delivering, and assessing mathematics instruction.

The preceding two case studies (Sheets & Heid, 1990; Lynch, Fischer, & Green, 1989) illustrate the need for mathematics instruction to focus on concepts and applications. Proper use of symbolic manipulation software with application problems will facilitate this change of focus (Swadener & Blubaugh, 1990). Bollinger (1989) discusses facts about
symbol manipulation programs and their relation to high school mathematics. He emphasizes that their incorporation into high school instruction is impractical because of their initial design for researchers, the high cost of purchasing computers, and because of the lack of a historical precedent for a machine doing symbolic computation as opposed to calculators which have been used since the early 1970s by business, scientists, and engineers.

The impression gained from reading published reports on using computer algebra systems in undergraduate education is that such use is part of isolated experiments rather than part of a rapidly growing trend. Bollinger (1989) agrees that it is easy to find predictions but difficult to find illuminating facts.

The push to incorporate symbolic mathematical systems in algebra is questionable because we are not sure of the relationships between procedural knowledge and skills and the understanding of algebra. The mathematics education community needs to determine the effects on mathematical understanding of the use of symbolic mathematics systems or any other device that carries out procedures before embracing them (Bollinger, 1989, p. 14).

The opinions in the literature assert some claims and raise some questions regarding computer algebra systems. Bollinger summarizes some of the claims:
1. They help with conceptual development. The time saved in calculations can be used to think about relevant mathematical concepts and to interpret output.

2. There is an increase in learning efficiency.

3. Students are introduced to an important future research tool.

Some of the questions that arise are:

1. What skill proficiency is needed to interpret the output?

2. Will the students actually spend more time investigating concepts if the machine does all the number crunching?

3. How will the curriculum content change to account for the use of symbolic manipulation programs?

4. Some students may use the computer at home to complete assignments. How would students from low income families receive equal treatment?

Bollinger's paper, though published in 1989, was actually written in 1987 before the appearance of the MET software. Although he raises some important questions, recent developments and purchases by high schools of computers and software make the symbolic manipulation program a viable choice for many educators. For many at this time, the greatest influence may be found in the use of these programs as a toy, one that can explore intriguing patterns. If they are used for their computational abilities, they will force a change from what has been traditionally emphasized. There
will be no algebra errors in long calculations. The mistakes will occur at the idea stage usually by a false assumption or a missing detail. This will force the students to think about problems at a deeper level thus promoting better understanding. The teachers will also need an inquiring mind with a vision towards the future.

Summary

The literature illustrates that the effects of computers in the mathematics classroom are varied. The computer uses range from individual CAI with minimum teacher intervention (Damarin et al., 1988) to computer laboratory situations with the inherent management challenges for the teacher (McGivney, 1990). The cooperative learning effects appear to be the most inspiring. In this context, problem-solving is the focus of most computer enhanced mathematics classes. The use of symbolic manipulation programs will enhance the problem-solving process and bring with them the promise of a new focus for computer enriched mathematics classrooms.

Summary of the Review of the Literature

The literature review highlights innovation and the changing curriculum, and the effects of computers inside the classroom. The changing roles of teachers and students present unique challenges, as do the many decisions the
teachers must make. The literature supports the new roles for teachers and students, the need for the development of new teaching skills, and the new resources that must be available for teachers (Heid, Sheets, & Matras, 1990; Olson, 1988; Corbitt, 1985; Krist, 1981).

Computers are often found in cooperative learning settings with the emphasis on problem solving skills. Hence cooperative learning is a predominant theme in each section of the literature review. The opinions and studies in the literature outline the potential of the computer and illuminate the salient features of a computer enhanced learning and teaching environment.

The literature contains many opinions about the potential of the computer as well as some concerns about the hazards of non-prudent use. The research into computer use in the classroom has not shown conclusive evidence that computer use is superior to traditional classroom methods. The opinions in the literature make predictions about the potential and leave the reader with a sense that the future of educational computing is yet to be determined and shaped.
This chapter will present a discussion of the case study methodology. As well, the site, including teachers, students, and software, will be described. The procedure used and the method of data collection and analysis will be outlined.

The Case Study Method

The case study, sometimes referred to as field research or ethnography, was chosen as the method of research. This choice was influenced by the work of Olson (1988). In his case studies, Olson’s goals were to witness and to understand both the "devils" and the joys of innovation. "Case studies are useful because they help us see first what practices signify, and they allow us to form judgements about the point of those practices" (Olson, 1988, p. viii). Olson sees his action research as a way of testing curricular ideas in practice. The tentative ideas of how the computer might function are made concrete. Action research allows teachers to become the designers of what the innovation is to be, through their analysis of their experience. When that experience is reviewed it becomes the basis for new experience. This case study includes one aspect of action research in that the author is also one of the subjects of the study.
Since the purpose of this study is to discover the factors involved when the computer is introduced into the traditional mathematics classroom, the case study method was deemed most appropriate. The case study method is generally used when studying contemporary events. "If a case study is about a new technology, for instance, observations of the technology at work are invaluable aids to any further understanding of the limits or problems with technology" (Yin, 1989, p. 91).

Day (1984) believes that if teachers are actively involved in research then more learning will be promoted by teachers and researchers. He also feels that if researchers are to achieve success, they must observe teachers in their natural settings. As Olson (1984) puts it, "[w]hat teachers know is in the practice not only in the cognitions that accompany practice" (p. 37). Bresler and Walker (1990) have the same concern. They refer to the notion of transferability which is "the extent to which the case study facilitates the drawing of inferences by the reader that may have applicability in his or her own context or situation" (p. 67).

The Site

The research site was a public secondary school in Vancouver, British Columbia. The over 900 students receive three hours per week of instruction in each of eight subjects. The classroom in which the case study took place was used
solely for teaching mathematics. The classroom was used every hour of the five hour (block) day (Figure 1).

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Figure 1. The 8x5 timetable

The teacher assigned to the classroom was Mr. Crosby (pseudonym), and he taught six classes there; the researcher taught two classes in this classroom. Thus the classroom was used continuously throughout the day with the exception of before and after school, and lunch hour. Mr. Crosby was usually in this classroom at 8:00 a.m. (classes actually began at 8:50 a.m.), and he was very often available during lunch time and after school as well, offering tutorial help to students.

The classroom (Figure 2) was equipped with tables and chairs, and conventional desks. The teacher’s lecture area was set up along the south wall. It consisted of a table on which sat an IBM model 50 computer and keyboard. There was no monitor attached to the teacher’s computer station as it would have made it difficult for the students at the very front of the classroom to see the teacher. Beside this table was a
trolley with an overhead projector and an overhead projection device connected to the computer. There was very little room for the teacher's books and notes. As well, the computer equipment and overhead projector required the use of power cords and extension cords which plugged into the south wall, about one metre behind the teacher. On this wall were white boards for writing. A projection screen was suspended from the ceiling about midway along the south wall.

Figure 2. Site Plan

The tables, chairs, and desks were arranged width-wise in the classroom. There were enough desks and chairs to
accommodate 35 students sitting in close proximity. There were windows with blackout curtains along the north wall. Below the windows along this wall, the heating registers were located. Built-in book shelves were situated along the west wall of the classroom. The 16 computer workstations were located along the west and north perimeter of the classroom. Each workstation contained a computer, monitor (black and white), and keyboard. There were two printers, one networked to all the workstations, and one connected to a single workstation. There were only a few extra chairs in the classroom, so most students had to move their chairs from the tables in the main area of the classroom to the computer stations. The fileserver was located at the beginning of the banks of computers. The main power switch was on the wall at the entrance to the classroom. It had a light indicator and was operated by a control key. The entrance door to the classroom was wired to the main security system of the school. The computer equipment was marked with school identification, but had no individual alarms.

The computers were purchased with school funds in January, 1991. Previous to that, they were in the school on loan from IBM Canada as part of a joint-study between IBM Canada and the Vancouver School Board, directed toward observing the use of The Mathematics Exploration Toolkit software, also an IBM marketed product.

IBM Canada accepted responsibility for servicing during the loan period (September, 1989 until December, 1990). After
that, maintenance and servicing was the school's responsibility. It was assumed by the teachers and administration that the district service personnel would service the equipment when necessary.

The Teachers

As mentioned above, there were two teachers involved in the study, Mr. Crosby and the author. Mr. Crosby had three years of experience teaching secondary mathematics but had little computer experience and certainly no formal training in computer use. He had received some technical training the previous year (as part of the joint-study agreement) on how to use the computer network, but was sometimes overwhelmed by the technical aspects. He received less than ten hours of training on the Mathematics Exploration Toolkit, the software used in the study. He did not have a computer at home but was very keen to try innovative ways of teaching mathematics.

There was a computer science teacher at the school who provided invaluable assistance to Mr. Crosby. In fact, in September, 1990, she introduced a network management course at the school. This was an elective course offered to students who had the prerequisite Computer Studies 11 course. After a few months in the course, the network management students were able to provide technical assistance to Mr. Crosby. They also provided assistance to the researcher during the present study.
The researcher had taken two courses on computer programming at university and had five years experience working with, and teaching about computers. She had given numerous workshops to colleagues on the use of computers. As well, she had seven years of Mathematics teaching experience. The researcher had just completed four years (part-time) of graduate courses at the University of British Columbia with a major in mathematics education and computer studies education. She had limited experience teaching mathematics with computers, although she had evaluated numerous pieces of mathematics software over the course of the previous six years, and she kept up-to-date with current literature.

The Students

The students observed were all enrolled in Mathematics 11. Three classes of mathematics were observed, the author’s class (block A), and Mr. Crosby’s two classes (blocks C and E). About 40% of Mr. Crosby’s students were known to the researcher as she had taught them mathematics in previous years. The students in general had had very little exposure to computers in a mathematics class, though many of them had experience using computers either at home or at school in data processing or computer studies classes.

There were 36 females and 33 males in total in the three classes. Block A had 10 females and 9 males, block C, 9 females and 14 males, and block E, 17 females and 10 males.
The researcher explained prior to the commencement of the study her dual role of teacher and researcher.

The Course and the Software

Mathematics 11 (British Columbia Ministry of Education, 1988) is one of three mathematics courses offered at the Grade 11 level in the school. It is the most challenging and is required as a pre-requisite for university entrance. It includes five topics: algebra (27%), relations and functions (25%), geometry (13%), trigonometry (25%), and data analysis (10%). The percentages refer to estimated instructional time. The Mathematics 11 Curriculum Guide states that it is expected that students use calculators throughout the course. In casual conversations with teachers, it was found that it was difficult for teachers to cover the content of the course in one school year (approximately 100 hours). As a result, most teachers did not teach the data analysis section.

The textbook used for the course was Mathematics 11 (Kelly, Alexander, Atkinson, & Swift, 1989). In designing the case study, the researcher decided that the teaching of the relations and functions topic would be the most appropriate to observe. This topic consisted of teaching many graphing skills. In Chapter 2, the literature included an example (Zehavi, 1988) of using the computer for teaching graphing at the secondary level, and there were many commercial software packages available at reasonable cost to teach that skill.
Mr. Crosby and the researcher decided to use the computer to assist in the teaching of chapters 6 and 7 of the textbook. Chapter 6 covers the quadratic functions, and chapter 7 covers transformations of relations. The teachers estimated that it would take 16 hours to cover these two chapters without the use of the computer.

The intended learning outcomes (ILOs) of the relations and functions unit from the curriculum guide are as follows:

11.23 Graph functions expressed as rules:
   a) constant functions
   b) linear functions
   c) powers
   d) reciprocal functions
   e) discontinuous functions
   f) absolute value functions

11.25 Graph and recognize the following relations:
   a) parabola
   b) circle

11.26 Show general changes in graphs resulting from changes in the defining equation:
   a) translation
   b) dilation
   c) reflection

11.27 Determine the equation of a relation given its graph.

11.28 Graph quadratic inequalities in two variables.
The textbook (Kelly, Alexander, Atkinson, & Swift, 1989) was organized such that chapter 6 introduced only the parabola, with each section introducing the three general changes, the translation, dilation, and reflection. The exercises in each section included drawing graphs and determining the equation given the graph (ILOS 11.25, 11.26, 11.27). Chapter 7 then introduced the other relations with each section applying the general changes to those graphs (ILOS 11.23, 11.25, 11.26, 11.27).

The Mathematics Exploration Toolkit (MET) permits the computer to be used as a function plotter, calculator, and symbolic manipulator. It is also possible to generate a table of values using MET. It is useful for teachers and students from algebra through introductory calculus. It provides on-screen help menus and a comprehensive tutorial. Teachers can prepare lessons by using defer sequences. These are sequences of commands which can be saved and executed at a later time. This allows the teacher to prepare a "slide show," for example, of graphs or steps necessary to solve an equation. The manual includes teaching ideas, sample presentations, and student worksheets related to each application, called guided explorations. MET requires MS-DOS computers with 512K RAM, and is in colour. It costs approximately $350 for a single copy, $1200 for a school package, or $2300 for a local area network (LAN) package.
Data Collection and Analysis

The data for this study were gathered during the period of January 28, 1991 to February 5, 1991. Within the week prior to observation, the researcher explained the nature and purpose of the study to the students. Students could opt not to participate by simply declining to answer questions.

The data were collected by means of direct observation. In Mr. Crosby's class the researcher took a seat at the back of the classroom and took field notes as Mr. Crosby delivered his lesson. When Mr. Crosby was finished presenting his lesson, the researcher circulated throughout the classroom. The field notes were jotted down during the observations and from them a detailed description of the events that took place, the people, the conversations among people, and the conversations with people was typed up each evening. The detailed notes also contained previously forgotten observations, analytic ideas, and personal impressions.

The data collection in the researcher's own class consisted mainly of mental notes, as she was only able to jot down notes when the students were actually working at the computer or at their desks. These notes also became written recollections. In this situation the researcher was at a disadvantage because there was insufficient time to take notes, but she did have the opportunity to observe reality from the "inside," and she had the advantage of being very familiar with the site and the students. Thus the data
collection consisted of looking, listening, and asking questions.

The most typical mode of qualitative data analysis is a narrative report (Miles & Huberman, 1984). The data gathering and data analysis may run concurrently, and the analysis relies heavily on description (Yin, 1989; Wiersma, 1986; Lofland, 1971). "The final stage of analysis occurring after observation has ceased becomes, then, a period for bringing final order into previously developed ideas" (Lofland, 1971, p. 118). The researcher found that, as she was typing up her field notes each evening, she was adding comments on her observations. Her experience with computers and students influenced her analysis of the data as she observed it. She recognized phenomena reported in the literature as she witnessed them in Mr. Crosby's classes and in her own class. Thus the analysis of the current research study will be in the form of a descriptive case study report, with the four research questions guiding the analysis.
CHAPTER 4

RESULTS

Introduction

This chapter presents the case study report, the descriptive narrative which will serve as the analysis of the current research study. The results will be presented as a chronological log of the observations in which the field notes have been condensed. Following the presentation of each observation or teaching session, the data will be analyzed in terms of site, teachers, students, curriculum, hardware and software, and any other features which emerge due to the analysis.

In total, eleven Mathematics 11 sessions were observed, six sessions taught by Mr. Crosby and five sessions taught by the researcher. In most of these sessions, the computer was used by the instructor and/or the students. In teaching the relations and functions unit, the researcher spent eight sessions (teaching hours), and Mr. Crosby used 12 teaching hours, both taking less than the 16 hours they had each projected. This could be due to the computer use, or in the researcher’s case, due to the fact that she combined chapters 6 and 7 from the textbook. Both teachers began teaching the unit at the same time, but the instructional period was interrupted by a crossgrade examination, the review classes
for the said examination, and a teacher's strike that lasted eight teaching days.

A Chronological Log of the Data

In order to impart the full flavour of what is involved in teaching mathematics with a computer, a capsule account of the field notes is included with this report. In preparing to document the events as observed, the researcher considered two options: the choice of organizing the data such that field notes of Mr. Crosby's classes were presented, followed by the notes relating the researcher's teaching sessions; or the second option of relating data as they occurred. The second option was deemed the most appropriate as the purpose of the case study was not to compare teaching styles but to document the specific aspects involved in the introduction of computers to the mathematics classroom.

Observation 1

Block A Lesson: Expansions, Compressions, and Reflections

The lesson began on time, at 8:50 with theory on the board. Nineteen students were present, ten females and nine males. The theory began with the listing of the six basic function equations which were $f(x) = x^2, f(x) = \sqrt{x}, f(x) = \frac{1}{x}, f(x) = 2^x, f(x) = x^3, f(x) = |x|$. The letter a was
introduced as a coefficient to those equations, for example, \( y=ax^2 \). In general, the teacher stated that if \( a>1 \), the equation indicated a vertical expansion. If \( 0<a<1 \), a vertical compression was indicated, and if \( a<0 \), the graph reflected in the x-axis.

The teacher then put the equation \( y=-2x^2 \) on the board and showed that according to the theory, this indicated a vertical expansion by a factor of 2, and a reflection in the x-axis. One student in particular could not understand how a factor of -2 indicated a vertical expansion since \( a \) was not greater than 1. The teacher explained that first expansions or compressions are considered by looking at the absolute value of \( a \), then, reflections are indicated by the sign of the coefficient.

At this point, the students were asked to go to the computers. There were 13 terminals available, which meant that six students would need to work with partners. In fact, only ten of the terminals were used, and the students worked in groups of two or three, of their own choosing.

The students were instructed to graph \( y=x^2 \) and then to graph \( y=2x^2 \). The teacher used the computer station and the overhead projection device to illustrate the graphs. The students were then asked for their observations. It seemed that everyone noticed that the second graph was narrower than the first. The teacher pointed out that this illustrated a vertical expansion. This concept was difficult for the students to grasp.
The teacher then asked the students to compare the points on the new graph to the basic equation. Not one student was able to make a correct comparison, and no one ventured to even guess; the students remained silent when called upon to give a response. The resolution on the computer screen and the scale of the grid were not very clear. The students had no idea how the graph expanded by a factor of 2. The teacher then instructed the students to graph the reflection \( y = -2x^2 \). The "flip" of the graph was obvious to them but the students did not appear to understand how the 2 was affecting the basic graph of \( y = x^2 \).

The teacher felt that she had done a poor job of introducing the theory, so she then used the computer graph which was projected on the white board to illustrate the factor change. She highlighted the point \((1,1)\) on the basic equation. Using the same \( x \)-value of 1, she then drew an arrow to the corresponding point on the expanded equation. She continued to do this for four different points, and the students were able to see that the \( y \)-values were doubling, or increasing by a factor of 2. At this point the lesson ended with the bell.

Discussion.

The teacher felt that using the computer actually hindered her presentation of expansions and compressions. The students were able to see the obvious, the reflection of the
graph, which is just a mirror image of the original graph, or a "flip" over the x-axis. The students could not see the expansion or the stretching of a graph until the teacher mechanically showed them the transformation of the points on the board. The board technique worked because the teacher explained and showed the expansion whereas the computer technique only showed, without an explanation, a graph different from the basic graph. The difference between a basic graph and an expanded or compressed graph can be subtle because of the non-linearity of the expression. Though the teacher used the computer image on the white board of the graph, she could have just as easily used an overhead transparency. This illustrates that the teacher chose to use a traditional board presentation because she did not see a way of highlighting the relationship between the points of the graphs by using the computer. In general, a visual presentation of compressions and expansions using a computer is usually more difficult to orchestrate than the presentation of translations and reflections. A traditional board presentation is easier because the students can follow the sequential construction of the graphs as opposed to an instantaneous display on the computer screen.

The teacher reflected on what she was doing and aborted her plan to use the computer in time to save the lesson, though there was not enough time to reinforce the concept with student practice. The student practice would not have included computer activities, but drawing a table of values
and plotting the points on paper with pencil. Lynch, Fischer, and Green (1989) observed that in the first year of their project, the class period often ended before closure on an idea had been achieved. As well, the teacher decided not to use the computer just because it was there, but to teach the lesson the best way she knew how.

It should be noted that the students had used the computer and the MET software earlier on in the year. They made a smooth transition from seatwork to computer stations and needed no instructions on using the software. The software was user friendly, meaning it was simple enough for the students to use without instructions from the teacher, even after not using it for a period of time. Also, there were only 19 students in this class, a relatively small class, and there was ample room for everybody at computer terminals. The students preferred to work in pairs, with the odd person choosing to form a group of three rather than work alone.

The description of the site in Chapter 3 indicated that there were 16 computer terminals, yet the data indicate that there were only 13 terminals available. The reason for this discrepancy is that one of the work stations was needed to operate the fileserver, and two of the work stations were not operating. Attempts to arrange for servicing were foiled, since IBM was no longer responsible for maintenance following the conclusion of the joint-study, and requests made to the district repair department were not answered. The teacher
eventually lost interest since 13 machines was a generous number for a class of 19.

This first observation illustrates three features of introducing the computer to the mathematics classroom:

1. This teacher did not have to use valuable class time to instruct the students on how to use the hardware or software. The students worked well in groups of two or three.

2. This particular use of the computer did not assist the teacher in meeting her lesson objective. When the students seemed confused, the teacher decided to revert to what amounted to a traditional method which seemed to be more effective.

3. The teacher had the added responsibility of arranging for the servicing of equipment.

Observation 2

Block C Lesson: Review of the parabola

The class began at 11:10 with eight females and 14 males present. Mr. Crosby talked about the symmetry displayed by the graph of a parabola. He sketched a general parabola \(y=x^2\) on the white board and then asked the students to specify the equation of the axis of symmetry. His question was an open question and not directed at any specific student; two or three students called out the correct answer.
The students were then asked to sketch the same graph, \( y=x^2 \), in their notebooks. They were reminded that they required graph paper in order to draw accurate graphs. As well, they were instructed to generate a table of values. The teacher made a table of values for this equation on the board and then sketched the graph so that the students could compare his graph with their notes.

The next example was \( y=x^2+3 \). Again the teacher constructed a table of values and showed that the graph was moving three units upwards because each of the \( y \) values had increased by 3 units. He then sketched the graph on the board and highlighted the vertex and showed that it had moved three units up. The teacher continued with one more example on the board, and the students worked individually drawing tables of values and graphs in their notebooks. By the last example only a few students were working on their own; they appeared to be waiting for the teacher to show the answer on the board. The teacher said that more board examples were required before they would get an opportunity to finish the previous day's exercises at the computer (the researcher was not present as this was before the study began). The teacher did one more example, \( y=x^2-2 \).

The students were then instructed to complete their computer exercises (Student Worksheet #1) from the previous day, working in the same groups. There was a textbook assignment for those students who had finished. The students rushed over to the computers with the exception of four.
females and one male who stayed at their desks. All the students worked in pairs, except for one group of three females. There were no male/female groups. The teacher gave some brief instructions about using the software and some special keys. The MET program began with a choice of either doing a tutorial or going directly to the program. Despite clear instructions on the screen and the teacher telling them not to do the tutorial, some students entered the tutorial and did not know how to get out.

The researcher moved around the room with the teacher and answered questions about the use of the software. The questions asked by the students were mostly about the software, rather than about the task at hand. The task was to complete a worksheet requiring the students to indicate the vertex of a graph and to sketch the graph. One student indicated to the researcher that he had done three or four of the questions using the computer then noticed a pattern, and completed the worksheet without the use of the computer. (This student left his partner earlier on and went to work by himself at another computer.)

Three more groups finished their worksheet but did not return to their desks to do the textbook assignment. These students remained at the computer and entered all kinds of different equations to see the effects on the graph. After about ten minutes at the computer, eight groups had finished their task and all remained at the computer and experimented with entering various equations. The five students who
initially stayed at their desks did not appear to be having difficulty with the textbook assignment which emphasized concepts developed by the computer exercises.

When the bell rang to indicate lunch hour, three students did not leave their work at the computer immediately. When all of the students had left the room, the researcher noticed that someone had altered the software so that it printed a rude message when the user chose to "quit."

Discussion.

In this lesson, the teacher did not use the computer at all for his presentation. Instead he used a table of values and hand generated graphs to illustrate his point. His students had had an introduction to the computers in the class before this one and seemed very eager to get back to their computer exercises. The computer was used to practice a concept already taught, and it seemed to achieve that goal successfully. The students worked eagerly and most finished their task quickly. They seemed to enjoy working with the computer. In fact, some used it as an excuse not to return to their desks to what the students perceived as the drudgery of written exercises.

The initial difficulty experienced by the students who were lost in the tutorial presented some frustrating moments. They all wanted assistance at the same time and did not read the instructions on the screen which indicated which key to
push to get back to the program. Despite the fact that the software itself was easy to use, the teacher should have reminded the students that they would first be given the choice in the main menu to use the tutorial. The researcher assisted the teacher by helping those students. The classroom was very crowded and it was difficult to get from one corner to the opposite corner quickly. The researcher, acting as an assistant to the teacher, made the teacher's job much easier. She assisted by one group of computers while the teacher assisted by the other.

As the students began experimenting with the various graphs they became curious, and questions were posed to the teacher. It was difficult for the teacher, and the researcher/assistant, to quickly study the graph on their display and indicate to them what they were seeing. In fact, with all the demands on the teacher, it was difficult to monitor what each student or group of students was doing. This is evident by the fact that one student had the expertise to alter the software. This is a good example of the loss of teacher influence as described by Olson (1988).

The teacher felt even more powerless because now that the rude message was on the screen; he did not know how to correct the deed and had to ask the computer science teacher who in turn had to ask one of her computer "whizzes" in the network management class to correct the software and tighten the security access to the fileserver. The teacher did not have the time to master the network management skills. This is
similar to what Tall (1987) observed in that if the system is used infrequently important skills are forgotten. In this study, the little training that the teacher did receive 16 months earlier was forgotten. His training did include the administration of the security of the network. Since he had forgotten some of those features, he allowed certain students access to the password which would enable them to tamper with the software. The data from this observation illustrate the looser class arrangements and the encouragement the students receive to try things out for themselves. Unfortunately, not everything they try for themselves is positive (like instructing the computer to print rude messages).

Heid, Sheets, and Matras (1990) discuss the decisions the teacher has to make regarding how much to explain about the process they (the teachers) were demonstrating and how much to leave to discovery. In this observation, the teacher used about 60% of the hour explaining, and the students seemed to get bored; perhaps he should have left more time for discovery. The worksheet was prepared by the researcher; in fact the researcher prepared all the worksheets in advance and correlated them to the textbook material and the curriculum. This was a time-consuming task and yet another responsibility of the teacher wishing to introduce computers to the mathematics classroom. There were very few questions from the students about the computer task, therefore the time spent designing a worksheet is worth every minute if the instructions and purpose are clear to the students.
As suggested above, the teacher perhaps should have included more relationships for the students to discover. In doing the worksheets, the computer was used more as a checking tool. The explorations came after the assigned work was completed as the students entered various equations and observed their graphs. Since the teacher had not organized an activity around these explorations, it is doubtful that much was gained. A useful activity would have been to write down an equation and describe it using a few sentences. The teacher had not designed an activity to capitalize on the exploratory nature of the computer. Regardless, the students experimented and were excited to be using a computer.

The students remained on task until they completed their worksheets, and some even stayed after the bell. The computer, being a novel mode of learning, seemed to capture the interest of the students. The cooperative group work seemed to be effective from the perspective that the students remained on task throughout the class, and it was noted that girls tended to work with girls, and boys worked with other boys. Though the students were instructed to take turns as keyboarders and recorders, it was difficult to determine whether the students actually rotated positions. As well, it was difficult to assess the understanding level of each individual student. Though the worksheet was completed, it was difficult to determine if the work was copied. Neither teacher planned to incorporate a computer component in their unit test.
Eight features stand out in the second observation:

1. The computer is a novel approach to teaching which captures the students' attention and enthusiasm, and lends itself to experimentation.

2. Because of the exploratory nature of many computer exercises, the teacher may not have answers readily available to questions. This can be very intimidating to a teacher as she/he relinquishes some of her/his influence.

3. The computer room should be planned in such a way that the teacher can see all the workstations and move freely among them.

4. Some students are more technically advanced than the teacher in their knowledge of computer systems, which can be intimidating to the teacher.

5. Lesson materials must be developed which correlate the computer lessons with the curriculum and the textbook.

6. The teacher received very little training in network management skills. Since the system was used so infrequently, the skills were easily forgotten.

7. In using the computer to teach the graphing of functions, the students should be allowed to explore the relationship between the graphs and the equations before being told what the correlation is.

8. Security of computer hardware and software is very critical. Passwords should not be shared with students.
Observation 3

Block E Lesson: Translations of the graph $y=x^2$

There were 27 students present in this afternoon class, 17 girls and 10 boys. The lesson began with Mr. Crosby informing the students that they would have an opportunity to work with the computers. He told them that they would be working in pairs and that they would be able to choose their own partners, but before the computer activities, he said, they would sketch some graphs in their notebooks using a table of values.

The students were asked to sketch the graph of $y=x^2$ using a table of values. The teacher sketched the graph at the same time as the students on the white board, then asked the students for their observations. One student said that it was purple (the teacher had used a purple pen). Another student said that it was symmetrical. The teacher used this last response to discuss the axis of symmetry.

The teacher did another example on the board as the students worked individually doing the same example in their notes. He then instructed the students to do some exercises from their textbook which required matching equations to graphs. The students did not appear to have difficulty doing so. Finally, the teacher put the equation $y=(x+2)^2$ on the board and asked the students to describe the translation without sketching the graph. There were many incorrect
responses before one student correctly identified the translation of two units to the left. Another student asked if there was any easy way to find that out.

The teacher then used the overhead projection device to show the students how to enter the MET program. He listed some of the important keys on the board. About two minutes later the students chose partners and went over to the computers. The teacher distributed one worksheet per group (Student Worksheets #2 and #3, which were printed back to back in their original form), and the students rushed over to get started. Many of the groups did not read the instructions on their screens and began with the tutorial rather than the actual program. The researcher helped those students by showing them the instructions on the screen that indicated that the F9 key needed to be pressed.

The computer work areas were crowded. The teacher circulated to make sure that all students had found a partner. One quiet student remained at his desk and the teacher found him a partner to work with. The teacher encouraged the students to use all of the terminals, but one terminal remained unused. The groupings were as follows: there were three groups of two males (MM); there were four groups of two females (FF); two groups of three females (FFF); one FFM group, one FMM group, and one male worked by himself.

The teacher continued to circulate around the room. He encouraged one of the girls in the FFF group to use the free computer station but she declined. It appeared that in the
groups, one student did all the typing while the others observed and filled in the worksheet. One female student left her group (FMM) and returned to her desk (this student had come to class ten minutes late). A particularly weak student seemed to be especially enjoying the computer activity and remarked: "I wouldn't be able to do this without the computer."

One female student complained that she could not work with other people and left her group (FFF) to sit at her desk. The researcher pointed out to her that there was an unused computer but she said, "forget it!" Otherwise, the groups worked through their worksheet exercises and stayed at the computer when finished and explored other equations. The teacher circulated and observed the students. At one point he assisted one group to use advanced features of the software. They "zoomed-in" by creating a window on the screen which amplified the display. By doing this they could accurately read the coordinates of the vertex. The bell rang to indicate the end of the school day, but two groups remained at the computer, exploring.

Discussion.

The teacher spent considerable time (about 25 minutes) in class sketching graphs using tables of values. This is necessary because the graphing software does not teach or reinforce the skill of drawing graphs. What it does reinforce
is recognizing graphs, given an equation. The students seemed to have no difficulty recognizing graphs when assigned the textbook exercises. The table of values is a valuable tool for recognizing the relationship between the $x$ and $y$ values, the domain and the range. The MET software is capable of generating a table of values for a given function but the students seemed to need the practice of plugging values into the equations and finding the range on their own.

The students had difficulty recognizing the translations on the board. They could see that the graph moved, but they could not specify how it moved, for example, that the original graph slid 4 units up, or 2 units to the left. In this case, the computer was able to generate graphs quickly, so that after seeing a few at their own workstations, the students were able to recognize the patterns and the relationship between the equation and the graph. Once again it was evident that the students were reluctant to read instructions on the computer screen, and some found themselves in the tutorial despite the teacher having taken the time to explain the software features to them. This was a relatively large class, and the researcher's assistance was appreciated in showing the students how to get into the program. This was not the first time this class had used the computer, and the teacher had taken the time to explain some of the key commands.

It was also evident in this class that boys tended to choose boys as partners, and girls tended to choose girls. The researcher decided to watch the division of labour closely
within the groups and observed that the students did not rotate duties. One person typed the whole time, the others watched and recorded. The teacher was kept very busy first of all ensuring that everyone was using the computers, and secondly watching that everyone was on task. Besides reminding the class periodically to rotate duties, there was not much he could do to guarantee that they did. In some situations, it is appropriate at a given time, perhaps halfway through the work period, to tell everyone to change duties. The difficulty with this method is that it discourages the assignment of duties based on personal working styles. The students remained on task and discussed the task continuously and seemed to enjoy working with the computer. In this study, it seemed that the students who could type usually did the typing, and those with the neatest handwriting usually recorded the information on the student worksheets.

The teacher distributed one worksheet per group, and the students were to hand it in for marking when complete. There were no criteria for individual accountability as the teacher planned to assign a group mark. There were no consequences for the student who left her group because the teacher was too busy helping other students to notice that she had not completed the work and her name remained on the worksheet with the group.

Despite the minor difficulty of students not reading the computer screen and entering the tutorial, the software was simple to use. The MET software is very powerful, though the
teacher gave the students only the basic commands necessary to complete the graphing. As the students became curious or as the teacher saw the opportunity, he would show individual groups some of the advanced features, for example, how to "zoom-in" or how to change the colour of the display (though the monitors were black and white, it was possible to obtain different shades of grey). Once one group started doing something different, the neighbouring groups would become curious and share strategies and discoveries. Thus there was no need for detailed instruction on the use of the software.

Once again it was evident that the student computer activities (Student Worksheets #1 and #2) replaced a textbook assignment and the computer was used as a tool for checking the correctness of their answers. But even in the checking, the students were required to interpret the graphic representations to determine if their answers were correct. Since the teacher spent considerable time sketching graphs on the board, the worksheets allowed the students time to practice the skills taught. The explorations began when the worksheets were finished. The students enjoyed creating patterns on the screen with the various shadings, and the explorations were more of an artistic nature than of a mathematical nature.

The groups of two seemed to be more effective than groups of three for mainly physical reasons. The computer stations were very close thus in a three person group, one person sat behind the other two and really was not part of the activity.
Also, in these graphing activities, there was no need for the distribution of social roles (as described by Male (1990)). The only roles needed were keyboarder and recorder. The computer activities did not require for example, timekeepers, checkers, or praisers as larger group activities would.

Eight features are evident in the third observation:
1. The students did not change roles or duties while on task.
2. Most students remained on task.
3. The teacher was kept very busy moving about through the crowded classroom.
4. The software was easy to use. No formal instruction was necessary. The teacher showed new features to individual students as the opportunity arose.
5. The students explored new features and shared discoveries with other groups.
6. Two person groups seemed more effective than three person groups.
7. There was no individual accountability for the work handed in for marking.
8. The worksheets were used for practice. The computer was used essentially as a checking tool.

Observation 4

Block A Lesson: Expansions, Compressions, Reflections
This lesson reviewed the concepts taught the previous day (documented in Observation 1). The author began by writing the equation $y=ax^2$ on the board and then proceeded to outline its features, that is, the vertex, the equation of the axis of symmetry, and the direction of opening. She then continued by discussing vertical expansions, compressions, and reflections in the $x$-axis. One student interrupted to ask if they were going to learn how to do the graphs on paper, not on the computer. The teacher answered that she would be assigning some textbook exercises that required drawing graphs on paper.

Three equations were written on the board and the students were instructed to complete the corresponding table of values. The equations were $y=x^2$, $y=2x^2$, and $y=0.5x^2$. The teacher allowed the students a few minutes to complete their tables, then she filled in her tables on the board. The students were now able to see how the $y$-coordinate increased or decreased by a factor of $a$. A student asked how they could draw the graphs easily by themselves without using the computer. The teacher replied that they would have to generate a table of values and draw the graphs on graph paper.

The teacher then used the computer and overhead projection device to graph those same equations. She labelled the graphs on the white board. She felt that this lesson was much more effective than the previous day's lesson. The teacher then proceeded to demonstrate other functions: the square root, the cubic, the reciprocal, and the absolute value.
function. Textbook exercises were assigned requiring the students to draw graphs using a table of values.

Discussion.

The computer was used in this lesson only in the teacher's presentation and was a time-saving device. The teacher realized that the computer could not help her teach how to draw a graph, or help the students learn how to draw a graph, thus there was no computer activity planned for the students. The teacher felt that the students needed the practice in mechanically drawing and completing a table of values, and then plotting their ordered pairs on graph paper. The teacher showed the emergence of the table of values on the board, and used the computer to draw the graph in order to show the students that the graph contained the points in the table (and infinitely many more). Thus the computer had very limited use in delivering this lesson.

Some of the students, on the other hand, had the maturity to realize that mechanically drawing graphs for themselves was an important skill they needed to master. Despite the fact that the computer was a useful tool and the students enjoyed using it, the student who interrupted the teacher to ask about the drawing of graphs, voiced a very valid concern. The teacher was not able to conceive a way of using the computer to assist the students in drawing graphs. With a different software program and a different data entry device, for
example a mouse, it may have been possible to actually draw a table and enter values. In fact, if there was a software program available which allowed the user to click on or point to the coordinates on a grid, and then joined the points to form a graph, a valuable computer lesson could be planned.

Thus, salient in this observation is the fact that:

1. This teacher chose a traditional teaching method because a way of incorporating the computer into the lesson was not conceived.

Observation 5

Block E Lesson: Translations, Expansions, Compressions of the Parabola

The teacher began the lesson by asking the students, "who has brought graph paper?" Not one person replied in the affirmative. He then proceeded with a review of the horizontal and vertical translations, moving into the review of vertical expansions and compressions. The teacher instructed the students to draw a table of values and sketch four graphs: \(y=2x^2\), \(y=2(x-3)^2\), \(y=2(x+2)^2-4\), \(y=0.5x^2+1\). All but four students appeared to be following the teacher’s instructions. The teacher sketched three of the four examples on the board.

After about 15 minutes of review, which included the sketching of the above examples, the teacher told the students
that they could go over to the computers. There was no
discussion of how changes to the equation related to changes
in the graph. The students were expected to check their work
with the sketches on the board. Students were instructed to
pick up one copy of the worksheet (Student Worksheet #4) for
their group. Although they could choose different partners,
the students formed the same groups and began work immediately
at the computers.

With 27 students present, the computer work area was
quite crowded. The groups preferred sitting side by side,
even the three person groups, thus one computer station was
not used since there was not enough room for even one person
to sit at it. There was one faulty computer station with a
non-functioning keyboard, at the end of one table, so the
researcher replaced the broken keyboard with the one from the
unused computer. Thus a group of two girls went over and used
this station. Only four students had to sit behind their
partners rather than beside.

The students were busy entering equations and specifying
information about their graphs. The teacher had not yet
introduced the concept of reflections, but the students
observed that some of the graphs "flipped" over the x-axis.
The worksheet required that the students specify the vertex,
concavity, axis of symmetry, and vertical compression or
expansion for given functions. They were then to check their
work by graphing. As mentioned above, the students entered
the equations first, then filled in the specific information.
They did not follow instructions and filled the worksheet after graphing the equations. When the students finished the assigned worksheet, they explored other equations. Two groups experimented with shading various parts of the coordinate plane, thus creating designs. One group tried to superimpose two parabolas to form a circle. Every group finished the assignment before the bell rang.

Discussion.

The teacher had intended to reinforce the graphing skills by asking the students to draw graphs using a table of values. But many of the students did not have graph paper and were probably just drawing sketches in their notebooks. Although he knew that the software would not provide practice in that skill he continued with the lesson as planned. It is possible that the teacher wished to continue with the lesson and send the students over to the computers because the researcher was in the room.

The computer exercises related to identifying how the transformed graph related to the basic graph. Although the computer was intended to be used as a checking tool for Student Worksheet #4, five of the 12 equations included a reflection, a transformation that the teacher had not introduced yet. Though the researcher noticed that some of the students commented on the graph flipping over the x-axis,
the teacher did not make mention of it in this class or in Observation 8, which was the next time this class met.

The computer area seemed more crowded. It could have been improved if the two non-functioning work stations were removed completely and the others moved over. The teacher did not have the technical expertise to disconnect cables and considering that the computers were not used that often, it probably was not worth the time and effort. The students did not seem to mind the crowded conditions because many of them would have been just as happy to sit back and watch one person do all the work. Again, there was no individual accountability. It appeared that the students enjoyed the computer activity as it was a change from the regular routine and it certainly encouraged looser class structure, that is, the students could talk and work with their friends. Thus, the students seemed to enjoy the computer situation rather than the work or the learning.

Only two of the groups experimented with creating designs. Though the computer affords the opportunity to explore, the majority of students are content to just complete the assigned work. It would be an even greater task for the teacher to design explorations beyond the curriculum, and there usually is not enough time in the curriculum for optional explorations. It is possible though, that by using the computer to teach certain topics, time will be saved, freeing the teacher to present optional topics. Then, once again, the development of materials to guide the explorations
requires time, which the teacher using innovative methods has in dwindling supply.

The researcher acted as an assistant to lessen the crowding. She would have liked to rearrange the physical set-up completely, but it was not her place to do so. Even in her dual role as teacher and researcher, she was a guest in her colleague’s classroom and used much discretion when making suggestions.

The following features must be considered when introducing computers into the mathematics classroom:

1. The site must be planned to facilitate group learning.

2. This teacher did not use the computer to teach about the drawing of graphs. The teacher felt most comfortable using traditional methods.

3. Follow-up exploration materials or worksheets should be designed and ready for use.

4. A technical assistant should be on call in the school, in order to help the teacher when problems arise such as replacing or repairing non-functioning equipment.

Observation 6

Block A Lesson: Translations, Expansions, Compressions of the Parabola
The lesson began with the author writing the general equation \( y = a(x-p)^2 + q \) on the board. She asked the students for all the information they could provide from this general equation. Together they established that given the general equation, the following information could be obtained using the \( a, p, \) and \( q \): the coordinates of the vertex, the direction of opening, the maximum or minimum, the equation of the axis of symmetry, the transformations (translations, expansions or compressions, reflections), and the intercepts.

The teacher handed out the worksheet (Student Worksheet #4), one per student, which required that the students specify the coordinates of the vertex, the equation of the axis of symmetry, the direction of opening, the basic equation, and the nature of the vertical expansion or compression. They were to check their answers by graphing the function on the computer. The students went directly over to the computers and began working, with the exception of three male students and one female student who generally displayed a negative attitude, with her comments about using the computer being no exception. This student left the classroom to go to the washroom. The remaining 18 students had no difficulties entering the software and worked diligently.

The student returned from the washroom and went over to an unused computer and actually enjoyed doing her assignment, much to the amazement and joy of her teacher. One male student left the computer after five minutes saying that he could fill in the worksheet at home. The other students who
remained at their desks, completed the worksheet without using the computer. The teacher had a difficult time making computer use mandatory since the work could be completed with paper and pencil only.

Discussion.

The teacher, in reflecting after the lesson, admitted that using the computer for the given exercises was not the most efficient method of completing the assignment. The worksheet instructions said "complete the chart then check by graphing the function." She realized that she should have instructed all of the students to work at their desks, and when the worksheet was completed, to go over to the computers to check their work. The computer for most students was a novelty and a break from the routine lecture/guided practice/assignment model, though the teacher generally maintained this style of teaching. The students who chose to work at their desks were bright students who did not need reinforcement from the computer activity nor the novelty of using the computer as a checking tool. Those students did not need to be motivated either. The teacher did not have a follow up activity prepared which would have challenged those students who did not wish to work at the computer.

It is evident in this observation that the computer presents a challenge to the teacher. The teacher is charged with the task of tapping the computer resources so that she
provides tutoring and reinforcement for the middle and low ability student and enrichment for the higher ability students. The teacher realized that there was no benefit in using computers just because they were there. Though the students received immediate feedback by checking the computer graphs as opposed to turning to the back of a textbook, they still had to read the graph for the vertex and axis of symmetry and make an interpretation for the vertical expansion or compression.

Therefore the predominant feature here is:

1. Teachers are challenged to plan activities and modify teaching styles in order to take advantage of the computer's potential.

Observation 7

Block C Lesson: Translations, Expansions, Compressions of the Parabola

Mr. Crosby used his computer and the overhead projection device to show the graph of a parabola. He reviewed the keyboard and some of the keys which could be used. He then showed some of the software commands that could be used. For example, TABLE generated a table of values given the lower and upper domain. He generated a table of values for a domain of -3 to +3. He noticed that some of the domain values were
rational and admitted that he did not know why. Upon further contemplation, the teacher realized that the TABLE command generated eleven ordered pairs each time it was invoked, thus he tried -5 to +5 and saw that the domain values were integers.

The teacher reviewed some of the transformations of the graph using his computer and the overhead projection device. At one point he assumed that he had generated a new graph (since his back was to the screen), but when he turned around, the previous graph still appeared. He quickly realized that he had forgotten to press the ENTER key.

The teacher put three more examples on the board and asked the students to describe the transformations. As the teacher lectured, one student sat at the back tapping on one of the keyboards. When the worksheets (Student Worksheet #4) were distributed, all of the students except one went over to the computers. All of the workstations were used by the 22 students, working individually or in groups of two. Once finished, the students entered equations spontaneously, some with very large integral exponents. The researcher showed some of the groups another piece of software called Green Globs (Dugdale & Kibbey, 1986). This software challenged the students to enter a correct equation to describe a given graph.
Discussion.

This observation highlights the importance to teachers of being familiar with the software before using it with a class. As well, it shows the difficulty in using a computer for demonstration if the teacher does not have a monitor. In this particular observation, the teacher had forgotten that the TABLE command automatically generates 11 ordered pairs. Many pieces of software, MET included, include so many features that it is difficult to remember them all. As well, the various commands and their results are easily forgotten if the software is used infrequently. On the other hand, if many different software programs are used frequently, it is easy to confuse commands and features.

Teachers are typically seen as authorities in their subject matter. This authority is constantly challenged when using the computer unless teachers have spent many hours testing and using the various features of the software. The changing role of teachers and students is emphasized here. The teacher is no longer the sole authority in the classroom. Mr. Crosby did not immediately realize how the TABLE command worked and realized the solution after about two minutes of reflection.

When addressing a class, the teacher usually attempts to be visible to all of the students and positions himself so that he can see the entire class. The teacher makes an effort not to turn his back when writing on the board and to be in
tune with the subtle interactions between himself and the
students, and between student to student. The computer used
as a demonstration tool introduces some physical constraints.
In this observation, the teacher was typing commands at the
keyboard with no monitor in front of him to verify the
results. He had to physically turn around to look at the
board behind him, and noticed then, that the wrong graph was
displayed. He re-entered the correct commands and obtained
the desired result.

The teacher in this observation was not flustered by the
errors he made at the keyboard, nor was he embarrassed when he
could not recall exactly how the TABLE command worked. This
was evident by his easy manner and relaxed rapport with the
students. He accepted his new role as a learner, learning
about computers on the job. He could have deferred the
problem to another time, or could have ignored it completely.
He established an atmosphere in the classroom where the
students were not concerned about the teacher’s lack of
knowledge and were challenged to assist him to find the
correct command or the accurate method of instructing the
computer. Even if the teacher had spent hours and hours
testing the software, the nature of computer exploration is
such that unexpected situations are always arising. It is
very difficult to anticipate many outcomes. This can be
compared to geometry proofs, for example, or the nature of
problem solving in general. Both these applications require
careful thought before suggesting a solution.
The MET software did not really challenge the students in this particular assignment. The students diligently completed the task of graphing the equations and identifying the vertex, axis of symmetry, maximum or minimum, and intercepts. They graphed the equations first rather than use the computer to check their answer as the worksheet instructed. The researcher introduced the Green Globs program to the students who were finished in order to sustain their interest and to challenge them further in graphing techniques. The teacher was not familiar with this program at this time, but quickly learned how to use it with the students. Once the researcher showed one group how to use it, the others quickly followed suit, facilitated by the user-friendly nature of the software.

It was noted that a student at the back of the room was tapping on the keyboard. This fact is significant in that one of the major security problems in the computer laboratory was protecting the keyboards from tampering. The caps on the keys could easily be removed, and the students often removed and rearranged them. Somehow, no one was ever caught in the process, but it was suspected that it was done by the students who sat at the back of the classroom while the teacher lectured. One suggestion for avoiding this is providing covers for the keyboards, but simpler still the students could be trained to slide the keyboards beside the computer or to put them on top when not in use.

Five features are evident here:
1. Teachers and students must accept their changing roles if computer implementation is to be successful and unstressful.

2. It is difficult for one instructor in a computer laboratory environment to monitor all on-going activities. For example, the researcher assisted by providing activities for those students who had finished their work.

3. Quality software makes computer implementation much more effective and simple to introduce as shown by the use of the Green Globs program.

4. Teachers must implement strict security measures to safeguard the computer equipment.

5. The site should be planned so that the teacher has a monitor at his computer station.

Observation 8

Block E  Lesson: Transformations of the Parabola

The researcher arrived five minutes after the class had started. Mr. Crosby was reviewing the concept of expanding and compressing the graph. The researcher sat down at the back of the room and noticed that the computers had not been turned on yet, (this was the first class of the day). The researcher turned on the fileserver and waited a few minutes but the computer would not boot (turn on). She tried a number of times, checked for loose connections, and then asked the
teacher if he knew that the network was down (not working); he did not.

The researcher left the room to find a student from the network management class (Donald, pseudonym). Donald was able to boot the computer after trying a few different things. The teacher was continuing with his review, following a similar routine as in previous classes, sketching graphs using a table of values. The researcher walked around and booted all the individual workstations, and by the time all the computers were up and running there were only ten minutes remaining in the period. The teacher assigned work from the textbook.

Discussion.

Mr. Crosby was able to carry on with his lesson without the use of the computer. He used the board to draw his sketches and then assigned work from the textbook. This is analogous to planning to show a film and having the projector break down. Teachers are trained to improvise when faced with unexpected events. The earlier observations show that the computer was never planned as an integral component of the lesson. The important point here is that the researcher, acting as an assistant, spent approximately 40 minutes attempting to get the computers to work (checking, finding Donald, watching Donald, booting the individual workstations). If the researcher had not taken the time to boot the network,
Thus, the one feature noted here is:

1. A technical assistant is critical to the maintenance of a computer laboratory in a school.

Observation 9

Block A Lesson: Review of Transformations: All Functions

The researcher began the lesson with a review of all the transformations. She placed an example on the board, and asked the students to list all the transformations from the basic equation. The teacher, using the overhead projector and a graph transparency, graphed the equation. Next, the teacher introduced the students to the Green Globs program using the teacher workstation and the overhead projection device to show the students how the program worked. This took approximately ten minutes.

The students were instructed to go over to the computers in pairs or by themselves and use the Green Globs program to identify the equations that matched the given graphs. They were told to do 20 questions then move on to the game component. All of the students went over to the computers and all of the workstations were used. At first they found that identifying the equations was a challenge. Of the 19 students present, one group of two and one girl working by herself did
not get to the game. Two of the male groups attempted a more challenging game called Tracker.

The students were relaxed and were enjoying themselves. Three groups continued playing even after the bell rang.

Discussion.

Illustrated here is the use of software which was simple and fun to use. The Green Globs program was introduced to the students by the teacher in a matter of minutes. It has high educational value and a relatively low purchase cost ($89). The Mathematics Exploration Toolkit is also very useful educationally, but for its purpose in this case study, it was not cost effective. The Green Globs program had the added feature of a game component, which kept the students' interest long after the assignment was finished. The motivation and enrichment features of the game made classroom management easier for the teacher.

The teacher was not asked any questions, and the students were challenged by the software. The teacher did not spend any lecture time guiding the students through activities which required stating the equation to match a given graph. The software was used to guide the activity. This illustrates a modification of the teaching style observed earlier. The classroom setting in this observation was ideal in that the teacher could circulate amongst the students, monitor progress, and ask probing questions to further challenge them.
Thus software selection is an important aspect of implementing computers in the classroom. The author feels that most of the quality software is at the elementary level. How then does the secondary teacher become aware of quality software and who provides the funds for its purchase?

In the present study, the researcher had been involved in the evaluation of software for many years and kept up-to-date with software reviews. She attended conferences annually, where software was often demonstrated. Green Globs, for example, proved to be such a popular program that a site license was negotiated by the district and the program is now available to all schools in the district at a cost of only $10. The other teacher in this study, Mr. Crosby, was not familiar with the available mathematics software and relied on advice from the district mathematics consultant and from colleagues.

The school in this study was fortunate to be part of the joint study between IBM and the school district; thus there were funds available for the purchase of software. The intent was to make the computer classroom/laboratory available to all mathematics classes. Mr. Crosby and the author were given the opportunity to recommend software for purchase based on software reviews and review of the software catalogues. Unfortunately, there was not enough software in the commercial market which correlated with the mathematics curricula in grades eight to twelve. This raises the issue of professional development and release time from teaching duties to learn
about new techniques and software. The discussion of this characteristic is beyond the scope of the current study.

Thus the above discussion stresses software features:

1. Quality, easy to use, simple to learn, challenging and entertaining software is very important for successful computer implementation.

2. This teacher allowed the software to guide the learning and altered her style of presenting board examples before assigning computer activities.

Observation 10

Block E Lesson: Review

Mr. Crosby was absent and there was a substitute teacher in his place. The researcher introduced herself to the substitute. The teacher told the students that they could spend the first 20 minutes using the Green Globs program, and then they were to review for the crossgrade exam scheduled for next week.

The researcher noticed that the computers had not been turned on, so she booted the system which took about ten minutes. The students indicated to the substitute teacher that they did not know how to use Green Globs, so the researcher gave a quick demonstration using the computer and the overhead projection device. The students were very
attentive and rushed over to the computers as soon as the researcher finished her presentation.

Although the students were instructed to use the component of the program where they were to enter the equation which matched the given graph, one group went immediately to the Green Globs game. The students worked well in their groups and continued playing the game after completing the graph matching exercises, until the end of the period (although they were given a review worksheet for the next week’s exam and were told to spend only 20 minutes at the computer).

Discussion.

One of the drawbacks of being innovative and trying techniques that others are not familiar with is that, when teachers are away, there is unlikely to be anyone to take their place and carry on. In this observation, the researcher filled in for the teacher (with the substitute’s permission). This stresses the importance of having technical or staff assistants on site to assist a substitute. These assistants should receive training at the beginning of the year in using all of the available software. Another alternative is training student assistants or monitors whose duties could include turning on and off the equipment.

This class was the large class of 27 students, but they posed no management or discipline problems for the substitute.
The students were familiar with the routine of finding partners and moving over to the computers. They were also engaged in an activity which they enjoyed and which kept them on task for the entire period. It was unrealistic to expect that they would stop playing the Green Globs game and do a review sheet of algebra questions when it was seen in earlier observations that it was difficult to get some groups to leave the computer when the bell rang.

The feature that dominates this observation is:

1. Good quality software will motivate and entertain students.

**Observation 11**

**Block A Lesson: Review for Crossgrade Examination**

The researcher wanted to make certain that the students knew how to graph their equations on paper. She handed out a short quiz where the students were required to draw the graph of \( y = -2(x+3)^2 - 1 \) using a table of values. After the quiz was collected the teacher distributed a review worksheet that the students were to complete at their desks. The review worksheet was for the crossgrade examination and included topics covered earlier in the year; it did not include the present topic, the graphing of functions.

Three females asked if they could use the computers. The teacher agreed. The three worked separately at the computers,
using the Green Globs program. Two of the students chose to match equations to the graph, the third played the game.

Discussion.

The teacher was bothered by the contradiction of using the computers in class, but not allowing their use on tests. She knew she was just starting to learn about incorporating the computer in the regular classroom, and decided to make it a personal goal to develop a test with a computer component for next year. The other difficulty was that the pending crossgrade exam was a cumulative examination given to all students in Mathematics 11 in the school, but not all students in the course were exposed to the computers. Thus an equity issue arises: if it was deemed that the computer enhanced the teaching and learning of mathematics, would those students exposed to its use have an advantage over the other students? And, if it was found that some students had an advantage, can computer use be mandated and teachers coerced to use them? This raises political and ethical questions, beyond the domain of the present study.

The teacher in this observation was bothered by another internal conflict. The objective of her lesson was that students practice skills learned in the term by completing a worksheet. Yet, three students wanted to use the computers instead. The teacher was pleased with their enthusiasm and wanted to encourage computer use (especially among girls).
She decided to allow them to use the computers and reminded them to complete their review at home. The only consequence would be that the teacher would not be available to assist them if they had difficulty with any question. The teacher made herself available after school on the day before the exam so the students could get tutoring if required. The question still remains, once the computer is introduced to the lessons, how can it be incorporated into the assessment process?

Thus the dominant feature here is:

1. Assessment instruments must be developed that include a computer component in order to evaluate the skills learned on the computer.

**Summary**

The chronological log of the observations is summarized in Table 1. The observation period was a very interesting one for the researcher. By observing Mr. Crosby and reflecting on her own teaching daily, she was able to make slight improvements with each class. For example, in Observation 7, while watching the students work, it occurred to the researcher to introduce the Green Globs program. Therefore, in her next class (Observation 9) the researcher included the introduction of Green Globs in her lesson plan. She was able to anticipate some of the questions and difficulties in advance. In turn, she and Mr. Crosby collaborated in lesson planning and frequently discussed their experiences informally.
after class. The documenting of the field notes each evening forced her to reflect on her teaching and Mr. Crosby's teaching, thus building the next lesson on the strengths of both teachers. The researcher has studied the literature on cooperative learning among students but the experience of the case study emphasized for her the advantages of cooperative teaching.

The chronological log presents two teachers' attempts to introduce computers into their mathematics teaching. The literature presented many views on innovation and the potential of computers in the mathematics classroom but the observations reveal that little innovation took place. In most of the observations, the teachers decided to proceed with their lectures without using the computer, and introduced the computer when they felt comfortable doing so. The students used the MET software primarily to check their work and for some very general explorations.

The features which have been outlined in the above discussions appeared repeatedly (Table 2) in many of the observations. Though the mathematics teaching (graphing of functions) occurred with minimal change over the two week period, there were ten salient features which influenced teacher and student routines. These features were the most significant for the researcher and will be summarized in the final chapter.
Table 1
A Chronological Log of the Observations

<table>
<thead>
<tr>
<th>Observation</th>
<th>Block</th>
<th>Date</th>
<th>Lesson</th>
<th>Text</th>
<th>ILO</th>
<th>Assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>01.28.91</td>
<td>$y = ax^2$</td>
<td>6-4</td>
<td>11.25a,11.26a,c</td>
<td>none</td>
</tr>
<tr>
<td>2</td>
<td>C</td>
<td>01.28.91</td>
<td>review of parabola</td>
<td>6-2/6-3</td>
<td>11.25a</td>
<td>Worksheets #1-3</td>
</tr>
<tr>
<td>3</td>
<td>E</td>
<td>01.28.91</td>
<td>$y = (x-p)^2 + q$</td>
<td>6-2/6-3</td>
<td>11.25a</td>
<td>Worksheets #2,#3</td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td>01.29.91</td>
<td>$y = ax^2$</td>
<td>6-4</td>
<td>11.25a,11.26b,c</td>
<td>Text: pp.209/249</td>
</tr>
<tr>
<td>5</td>
<td>E</td>
<td>01.30.91</td>
<td>$y = a(x-p)^2 + q$</td>
<td>6-5</td>
<td>11.25a</td>
<td>Worksheet #4</td>
</tr>
<tr>
<td>6</td>
<td>A</td>
<td>01.31.91</td>
<td>$y = a(x-p)^2 + q$</td>
<td>6-5</td>
<td>11.25a</td>
<td>Worksheet #4</td>
</tr>
<tr>
<td>7</td>
<td>C</td>
<td>01.31.91</td>
<td>$y = a(x-p)^2 + q$</td>
<td>6-5</td>
<td>11.25a</td>
<td>Worksheet #4</td>
</tr>
<tr>
<td>8</td>
<td>E</td>
<td>02.01.91</td>
<td>$y = a(x-p)^2 + q$</td>
<td>6-5</td>
<td>11.25a</td>
<td>Text: pp.211-212</td>
</tr>
<tr>
<td>9</td>
<td>A</td>
<td>02.04.91</td>
<td>Review Transformations all Fncns</td>
<td>6-5</td>
<td>11.26a-c,11.27</td>
<td>Use Green Globs</td>
</tr>
<tr>
<td>10</td>
<td>E</td>
<td>02.04.91</td>
<td>Review</td>
<td>-</td>
<td>-</td>
<td>none</td>
</tr>
<tr>
<td>11</td>
<td>A</td>
<td>02.05.91</td>
<td>Review Quiz</td>
<td>7-5/7-6</td>
<td></td>
<td>Use Green Globs, Review</td>
</tr>
</tbody>
</table>
Table 2
Salient Features of Computer Use

<table>
<thead>
<tr>
<th>Feature</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality Software</td>
<td>4, 7, 9, 10</td>
</tr>
<tr>
<td>Method (Traditional vs computer)</td>
<td>1, 3, 5, 6</td>
</tr>
<tr>
<td>Assistants</td>
<td>1, 5, 7, 8, 10</td>
</tr>
<tr>
<td>Motivation/Exploration</td>
<td>2, 3, 4, 11</td>
</tr>
<tr>
<td>Teacher role</td>
<td>2</td>
</tr>
<tr>
<td>Site</td>
<td>2, 4, 5, 7</td>
</tr>
<tr>
<td>Lesson Materials</td>
<td>2, 5</td>
</tr>
<tr>
<td>Professional development</td>
<td>2</td>
</tr>
<tr>
<td>Cooperative learning</td>
<td>1, 3, 4, 5</td>
</tr>
<tr>
<td>Accountability/assessment</td>
<td>6, 11</td>
</tr>
</tbody>
</table>
CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This final chapter of the case study report on the introduction of computers to the secondary mathematics classroom will summarize the results reported in Chapter 4. The research questions posed in the first chapter will be addressed, and recommendations for practice and future research will be made.

The researcher reported on her observations in three Mathematics 11 classrooms, her own, and Mr. Crosby's two classes. The computer was used to supplement the teaching of a unit on graphing relations and functions. The data indicate that three intended learning outcomes (as described in Chapter 3) were addressed in the observation period, ILOs 11.25a, 11.26, and 11.27. The summary of the field notes is included in Chapter 4 so that the readers can apply them to their own context, as suggested by Bresler and Walker (1990). The two teachers were actively involved in the research thus promoting their own learning, as described by Day (1984), and establishing the teacher as a learner.

Summary of Observations

The Site

The site, in terms of studying the introduction of computers into a mathematics classroom, was nearly ideal. The
mathematics classroom and the computer laboratory were one in
the same. There were 16 workstations, sufficient to
accommodate all the students in groups of no more than two.
The computers were networked so that the teacher did not have
to worry about distributing and managing software. The
teacher had a computer workstation outfitted with an overhead
projection device. There were funds available for the
purchase of software. All of the above conditions seem ideal
for establishing a computer enriched environment, and they
are, almost. The deficiencies of the site did not seem to
hinder the teachers in the study but are included in the
spirit of recommendations for those readers planning their own
computer site and the necessary resources.

The classroom was not designed to accommodate computers.
The room was very crowded, as reported in the data. The
computers on one side were close to the heating registers,
thus exposed to dust and direct heat. They were sitting on
conventional tables, approximately 2.5 metres in length, and
did not accommodate groups of students comfortably.

The black and white monitors were adequate, but colour
Displays would have been more effective, especially for
showing the contrast between a basic graph and a transformed
d graph. It was mentioned in Chapter 3 that the teacher's
workstation did not have a monitor, thus it was difficult for
the teacher to see the results of his demonstrations. Had he
been supplied with a lower table specifically designed for a
computer, he would have been able to use a monitor, and the
students at the front of the classroom would not have had any difficulty seeing over it.

The size and shape of the classroom were also restricting in that when sitting at the computers the students had their backs to the teacher. This arrangement discourages interactive demonstrations, where the teacher demonstrates some feature, and the students immediately try it for themselves.

It is the opinion of the author that the lack of a service or repair arrangement is a serious oversight. It is unwise to purchase computer equipment without establishing who will be responsible for its repair. The other feature regarding the site, which the author perceives to be of a serious nature, is the inattention to security. The room was left unlocked in the teacher's absence, and the computers were not secured to the tables or interconnected in some fashion to discourage theft. As well, the keyboards were a prime target for bored or mischievous students. These are the physical security weaknesses.

The integrity and protection of the software must also be maintained. Mr. Crosby, being a novice computer user, was not aware of some of the potential hazards such as software tampering or computer viruses. The access to the fileserver should have been limited to teachers only, and even the advanced network management students should not have been given the password to access the fileserver.
The Teachers

The teachers in this study were not frightened of using computers; if anything, they worked hard to try to tap the computers' resources. They realized that integrating the computer in their mathematics teaching was a challenge, and this study documents some of those challenges.

The two teachers did experience some of the problems to which Lampert (1985) referred, for example, hardware not functioning or realizing that the lesson could have been taught better using traditional methods. The teachers were flexible and worked around the site drawbacks discussed in the previous section. They heard in workshops of the great potential of the computer in displaying graphs and promoting exploration but they still remained challenged to develop wise use of the computer. They began their teaching unit expecting to use the computer for all of the lessons. Instead, they graphed quite a few examples on the board or on the overhead projector because they could not conceive of ways of using the computer to demonstrate the relationship between the picture of the graph and the actual values.

The teachers did not really set detailed goals with respect to computer use. They were learning "on the job" what some of those goals could be. They did realize, however, that they had to improve on their worksheet materials and had to use those worksheets to promote learning by exploration. The current study supports Lynch, Fischer, and Green's (1989)
assertion that "finding the right combination of challenge and support for students in laboratory sessions is not an easy task" (p. 691).

The teachers were disappointed that they did not have the time to explore other capabilities of the computer and the software, but they hoped to do so in the future. Collis (1988) emphasized that teachers do not have the time to find uses for school computers. The two teachers in the study felt obligated to use the computers more than they did, and a little bit guilty that such a computer enriched classroom was not being put to its most cost effective use. The literature supports the realization that the changes in teaching and learning have to be gradual and that it is unrealistic to expect teachers to incorporate technological innovations immediately (Cuban, 1986; Fey, 1984). This highlights the urgency of professional development activities.

The teachers in the study remained undaunted by the negative aspects of computer implementation. They were still enthusiastic about the challenges that were involved in attempting to implement computers in the mathematics classroom, primarily because of their knowledge of the widespread use of computer technology in industry and research and the rapid advances and developments in both hardware and software. They would have greatly benefitted from professional development activities which presented materials that they could incorporate into their teaching. It is important that the leaders in computer applications in the
curriculum meet and exchange ideas and techniques relevant to particular subject matter. The difficulty is that very few teachers consider themselves leaders, and the teachers in the current study are no exception. The pooling together of the gradual changes that each individual makes would create a rich resource of computer applications in mathematics.

The Students

The students in the present study adapted to the altered routine in their mathematics classes very quickly. They usually rushed over to the computers when given the cue from the teacher, and as noted in the observations, they generally remained on task. The students worked together readily and presented few discipline problems. They did not abuse the looser classroom structure, the transition from seatwork to computer work went smoothly, and they generally remained on task.

The researcher predicted at the onset of the study that there would be more conversations to monitor. She found that there was very little idle chatter, and the conversations were usually task related. Fey (1984) wondered whether teachers could prepare their students for working in a technological environment by making only modest changes in class activity. It was inferred that the computer was a highly motivating feature in the mathematics classroom which was evident from the observations of the students. It was a change of routine,
and the students were able to work with their friends. Since there was no evaluation attached to the computer exercises, that is, no test or exam, the students viewed the computer activities as fun activities, especially when the Green Globs program included an actual game.

**The Course and the Software**

This study relates two teachers' experiences teaching the unit on graphing relations and functions, and it is suspected that there are probably other topics in the Mathematics 11 course that lend themselves to computer use. The teachers had predicted that they would require about 16 teaching hours to cover the entire unit, learning outcomes 11.23, 11.25-11.28. The researcher observed ILOs 11.25a, 11.26, and 11.27 as reported in Chapter 4. This is about 60% of the material included in the unit, and the teachers used on the average eight teaching hours. It is suspected that the entire unit would have required about 13 teaching hours, using the computer. A follow up study would be required to determine if there actually is a time saving.

Two software programs were used during the observation period, the Mathematics Exploration Toolkit (MET) and Green Globs. In designing the study, in consultation with Mr. Crosby, it had been intended to use only MET, but it was concluded that MET was not challenging enough for the chosen goal of teaching about the graphing of functions, thus the
program Green Globs was introduced to the students. MET is a powerful program with its symbolic manipulation capabilities and the defer sequence programming feature. Both teachers involved in the study felt that they needed much more practice before they became proficient in its use and before they could adapt it to other topics in the curriculum.

The teachers were not able to correlate ILOs 11.25a and 11.26 with the MET software. These ILOs required that the students graph and recognize the parabola and, show general transformations from a basic equation. The teachers used the overhead or board to illustrate the graphing techniques and the effects of the $a$, $p$, and $q$ in the general equation $y = af(x-p)+q$. The MET software was primarily used for checking the correctness of the answers. Though using the computer was a novel way of checking answers, MET also allowed the students the opportunity to create artistic patterns by superimposing graphs and altering the shading which some students used. However, when compared to Green Globs MET held very little appeal for the students.

Green Globs was introduced because it could give the students practice in determining the equation of a relation given its graph (ILO 11.27). As well, it could be used as a checking tool, and it included a game which required that the students enter equations to intersect points (green globs) randomly placed on the screen. Green Globs was easy to learn and use and could have been used exclusively to teach ILOs 11.25a, 11.26 and 11.27.
The defer sequence programming feature of MET offers teachers an opportunity to create their own presentations. It would be useful for teachers interested in using MET to meet and develop presentations and guided explorations. The teachers in this study did not get an opportunity to explore this feature of MET.

The Research Questions

Four research questions were posed in Chapter 1:

What salient features emerge in the mathematics classroom when the computer is used to teach a graphing unit?

How do the teachers adapt the use of the computer to the graphing topic and the already established classroom routine and setting?

How do the students adapt to the computer-based learning activities they experience?

What advantages and/or disadvantages do the teachers and students experience when using the computer?
Salient Features

The salient features which emerged from the study of introducing the computer to a mathematics classroom are summarized below. In the assessment of the features, some recommendations for practice are included.

1. Quality software

Quality software ensures that the teacher will not have to spend many instructional hours teaching about its use. It also facilitates better management of the computer learning environment. Both of the software programs used in the study were user-friendly in that the students used them with very little direction from the teacher. The chosen software should match the curriculum objectives and promote student learning.

2. Traditional methods versus computer-use

The teacher must be flexible and constantly needs to make decisions about when and when not to use the computer. These decisions are based on experience, and this study shows that with limited experience using computers in a mathematics class the teachers relied on the more familiar traditional board methods and used the computer mainly for the student assignments.

3. Technical/Staff Assistants

Assistants are required in a computer laboratory as they are in science laboratories. The teacher usually does not have the time to become a technical expert, and someone needs
to be on-site to assist with the laboratory when the teacher is away. An in-school assistant should be on-call full time to maintain the network and service the machines. Districts should provide resource people who could be available to assist with software difficulties and to offer advice on how to correlate software with curriculum content.

4. Motivation and Exploration

The computer tends to be a motivating device, awakening students from complacency or lethargy. The students tend to remain on task and tend to have the desire to explore deeper into the topics being studied. It is possible, however, that the novelty of using a computer in a mathematics class contributed to the high degree of motivation observed.

5. Teacher Role

The changing role for teachers and students challenges the teacher's traditional role of provider of information. The teacher may not always have the answers readily available and may not have the same technical expertise as some students. The teacher must not only be prepared to answer, "I don't know," but must also be prepared to learn from on the job experiences.

6. Site

The physical site must be planned carefully to facilitate the ease of movement, group learning, vantage points, and security.
7. Lesson materials

The lesson materials must be self-explanatory so that they make use of the computer's potential as well as correlate with the curriculum. The tasks should accommodate more than one ability level.

8. Professional Development

Teachers need release time to train in the use of computers in mathematics and in technical aspects relating to a computer environment. Teachers need to find more uses for the computers in mathematics class so that the computers are used more often and are cost effective. Teachers need to use the computers more often so that they do not forget their skills.

9. Cooperative learning

The students teach each other about the software, and they share discoveries. It was found that groups of two were more effective than groups of three because it was more difficult for three students to see the monitor clearly.

10. Accountability and Assessment

The teacher needs to pre-set guidelines for individual accountability and needs to develop an instrument (quiz, activity, etc.) to assess individual students on their computer activities in order to determine if the computer lesson is actually effective.
How the Teachers Adapt

The study shows that the teachers adapted to the obstacles inherent in the computer environment. They moved about the crowded classroom, helping and observing students. They chose traditional teaching methods or their usual method of teaching and used the computer when they felt comfortable doing so. The teachers did not really adapt the computer to their teaching style or to the curriculum, but they did use it to project certain graphs on the white board.

The teachers encouraged the students to work in groups. In the larger classes it was necessary to work in groups of two or three. Worksheets were distributed as assignments though the teachers did not adapt their evaluation procedures as no group marks were assigned. In fact, no assessment took place on the computer activities. Although the computer was used by the students mainly for practice and checking, it was evident from the observations that the teachers were challenged by the physical computer environment and did not adapt the computer to the curriculum as much as they had hoped. It was only with the introduction of the Green Globs program that the teachers relinquished some of their control over lesson presentation to the computer and the software. Perhaps the two week observation period was too short a time to expect adjustments to teaching style and presentation.
How the Students Adapt

The students had the opportunity to work in groups, in a more relaxed atmosphere than the traditional classroom. They did not seem to take advantage of the looser classroom arrangements and remained on task during their assigned activities helping each other. In fact, some students continued their work on the computer after the bell rang to end class.

Many of the students explored some of the additional features of the MET software without prompting from the teacher. The students used the Green Globs program without any difficulty and learned the game rules very quickly. The students seemed to adapt their work habits to the computer environment quite quickly, but the study was not able assess how student learning was affected.

Advantages and Disadvantages

The advantage of using the computer to teach and to learn is that it is highly motivational for the students. It facilitates cooperative learning and provides self-guided activities which allow the teacher the freedom to circulate amongst the students and monitor their progress. Given the proper software, the students can explore topics in greater detail than presented by the teacher and choose a level of difficulty appropriate to their own personal skill ability, as
shown through the use of the Green Globs software. Unfortunately, the relatively short duration of this study did not permit the opportunity to evaluate these advantages.

The software can also pose a disadvantage in that it is not all inclusive. For example, in this study, it could not teach the manual skills required to draw a graph. Another disadvantage is that a computer environment creates more work for teachers in that they have to prepare lesson materials to correlate the curriculum with the software and they have to contend with technical and mechanical problems in the operation of the hardware and the software. The site itself can also be an inconvenience, in that the computer sites in most schools are not usually designed specifically to suit computers, but rather the classrooms are adapted after the fact.

Conclusions

Integrating computers in the mathematics classroom is a realistic goal. This research study illustrates that the process of implementation must proceed one step at a time with careful planning and clear goal setting with regard to teaching and evaluation objectives. This study shows that there is a substantial amount of effort required in implementing computers in the Mathematics 11 curriculum. Since effort is relative to the individuals involved, the research could not determine if there were more successes or
difficulties. The teachers in this study were not discouraged; in fact, they were challenged to attempt to improve on their computer enriched unit. They also hoped to find other areas in the mathematics curriculum in general where they could implement the computers.

The computer provided a challenge to the teachers in the study, as does any innovation. However, to initiate the innovative process teachers need the desire and curiosity. Once that process commences, the challenges and the successes are the fuel which drive the innovation. The teachers in this study introduced the computer into their teaching routine, but for the most part used the traditional method of lecture and assignment. The observations illustrate the "idea taking hold" as described by Ellis (1990) and that even with a gradual and limited introduction of computers into the mathematics classroom, many factors must be considered. These factors were framed in the discussion of the research questions.

**Recommendations for Practice**

It is recommended the teachers create an environment in a computer setting where students must accept greater responsibility for their own learning, and where these students must find new ways of assessing their understanding. The classroom lessons in the non-traditional program must be developed so that they interface with the computer activities.
and with the prescribed textbook. The lessons must include not only the subject matter but software and hardware features and problem-solving strategies as well. The teacher wishing to integrate computers in the mathematics classroom must have a vision of the future and make decisions on whether the computer is actually an effective alternative or a complement in the classroom.

The responsibility for security should be at two levels. The administration should be responsible for establishing the guidelines; the teacher’s task would then be to enforce them. It should be noted that enforcement is difficult when many teachers use the same computer laboratory, and in that case a staff assistant should be responsible for enforcement. In the case of maintenance, again the administration should be responsible for establishing a contract or entering into an arrangement with the appropriate district department or an independent contractor.

Though it has been stated that teachers working in a computer environment have very little time to spare, they should make every effort to search for quality software and evaluate available software before introducing it for use in the classroom.

Recommendations for Future Research

The emergence of the ten features listed earlier is the predominant result of the current research study. Two of
those features are recommended for future inquiry. The students appeared to be motivated, and they displayed a very positive attitude. This could have been a result of the novelty of the computer experience. Would these students remain motivated over the long term, after the novelty wore off?

The other feature which is recommended for future study is the evaluation instrument. In this case study, there were no tests or quizzes on the computer activities. What type of instrument would be appropriate for a computer integrated mathematics course?

The graphics calculator has become very popular since this study was carried out. In fact, at the school in the study thirty graphics calculators are available for use at all grade levels (appropriate for grades 10-12). Some students even own their own. Future research will indicate whether they are effective in teaching graphing techniques, and a comparison of computer use and graphics calculator use would be pertinent.

Qualitative research has highlighted many of the components of a computer integrated mathematics class. This study has explored the potential of the computer in the mathematics classroom, and it has raised some important challenges for teachers. Future quantitative research will help to determine the effectiveness of some of the techniques illustrated in the present study.
BIBLIOGRAPHY


138


APPENDIX

Student Worksheets

Student Worksheet #1

<table>
<thead>
<tr>
<th>Step</th>
<th>Enter</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>CLR F</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>SCALE 10</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>y = x^2</td>
<td>Type the function</td>
</tr>
<tr>
<td>4.</td>
<td>(F12)</td>
<td>Graph the function</td>
</tr>
<tr>
<td>5.</td>
<td>x = 0</td>
<td>Type the axis of symmetry</td>
</tr>
<tr>
<td>6.</td>
<td>(F12)</td>
<td>Graph the axis of symmetry</td>
</tr>
</tbody>
</table>

7. Complete the charts. Graph each of the equations below. Use the graph to complete the table.

(Create your own equation for 10 and 11)

<table>
<thead>
<tr>
<th>I. Function</th>
<th>Vertex</th>
<th>Axis of Sym.</th>
<th>Dir. of Translation from y = x^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>e.g., y = (x-3)^2 + 2</td>
<td>(3,2)</td>
<td>x-3 = 0</td>
<td>right 3 units, up to 2</td>
</tr>
<tr>
<td>1. y = x^2 - 2</td>
<td>(3,2)</td>
<td>x = 3</td>
<td></td>
</tr>
<tr>
<td>2. y = (x - 2)^2</td>
<td>(3,2)</td>
<td>x = 3</td>
<td></td>
</tr>
<tr>
<td>3. y = (x + 5)^2</td>
<td>(3,2)</td>
<td>x = -5</td>
<td></td>
</tr>
<tr>
<td>4. y = (x + 7)^2-3</td>
<td>(3,2)</td>
<td>x = -7</td>
<td></td>
</tr>
<tr>
<td>5. y = x^2 + 5</td>
<td>(3,2)</td>
<td>x = 0</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>(3,2)</td>
<td>x = 0</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>(3,2)</td>
<td>x = 0</td>
<td>left 1 unit, up 2 units</td>
</tr>
<tr>
<td>8.</td>
<td>(3,2)</td>
<td>x = 0</td>
<td>down 3 units</td>
</tr>
<tr>
<td>9.</td>
<td>(-8,0)</td>
<td>x = -8</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Graph the following equations and complete the table.

<table>
<thead>
<tr>
<th>Function</th>
<th>Coordinates of a &quot;Significant Point&quot;</th>
<th>Translation</th>
<th>Type of Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. (a) $y = x^2$</td>
<td>(0,0)</td>
<td>---</td>
<td>quadratic</td>
</tr>
<tr>
<td>(b) $y = x^2 + 3$</td>
<td></td>
<td>3 up</td>
<td>quadratic</td>
</tr>
<tr>
<td>(c) $y = (x-2)^2$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(d) $y = (x+5)^2 - 6$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. (a) $y = \frac{1}{x}$</td>
<td>(1,1)</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>(b) $y = \frac{1}{x+3}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) $y = \frac{1}{x} + 3$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(d) $y = \frac{1}{x-2} + 6$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. (a) $y = x$</td>
<td>(0,0)</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>(b) $y = x + 8$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) $y = x - 5$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(d) $y = x + 2 - 5$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. (a) $y =</td>
<td>x</td>
<td>$</td>
<td>(0,0)</td>
</tr>
<tr>
<td>(b) $y =</td>
<td>x - 4</td>
<td>$</td>
<td></td>
</tr>
<tr>
<td>(c) $y =</td>
<td>x + 4</td>
<td>$</td>
<td></td>
</tr>
<tr>
<td>(d) $y =</td>
<td>x - 2</td>
<td>- 2$</td>
<td></td>
</tr>
<tr>
<td>Function</td>
<td>Coordinates of a &quot;Significant Point&quot;</td>
<td>Translation</td>
<td>Type of Function</td>
</tr>
<tr>
<td>-------------------</td>
<td>--------------------------------------</td>
<td>-------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>5. (a) y = x^3</td>
<td>(0,0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) y = (x + 3)^3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) y = x^3 - 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(d) y = (x-2)^3 + 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. (a) y = 2^x</td>
<td>(0,0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) y = 2^x + 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) y = 2^x+3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(d) y = 2^{x-1} - 8</td>
<td></td>
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</tr>
</tbody>
</table>
Student Worksheet #4

\[ x - p = 0 \text{ is the axis of symmetry} \]
\[ y = a(x - p)^2 + q \]

coordinates of vertex are \((p, q)\)

congruent to \(y = ax^2\)

concave up if \(a > 0\)
concave down if \(a < 0\)

vertical expansion if \(a > 1\) or \(a < -1\)
Vertical compression if \(-1 < a < 1\)

Complete this chart then check by graphing the function.

<table>
<thead>
<tr>
<th>Function</th>
<th>Vertex</th>
<th>Concavity</th>
<th>Axis of Symmetry</th>
<th>Congruent to:</th>
<th>Vertical compression or expansion</th>
</tr>
</thead>
<tbody>
<tr>
<td>c.g.. [ y = -3(x+2)^2 + 1 ]</td>
<td>(-2, 1)</td>
<td>down</td>
<td>[ x + 2 = 0 ] [ x = -2 ]</td>
<td>[ y = -3x^2 ]</td>
<td>vertical expansion</td>
</tr>
<tr>
<td>1. [ y = .5(x-1)^2 - 2 ]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. [ y = -1.5(x+3)^2 + 5 ]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. [ y = (x-7)^2 - 2 ]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. [ y = -(x-2)^2 - 5 ]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. [ y = 5.2(x-3)^2 + 7 ]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. [ y = \frac{1}{5}(x+3.2)^2 - 6.7 ]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 1. \[ y = -(x+2.5)^2 + 3 \] | | | | | |
| 2. \[ y = -2.5(x-1.6)^2 - 3 \] | | | | | |
| 3. \[ y - 5 = 3(x+2)^2 \] | | | | | |
| 4. \[ y = 3x^2 - 7 \] | | | | | |
| 5. \[ y - 2 = x^2 \] | | | | | |
| 6. \[ y = 3-2x^2 \] | | | | | |