

The Effectiveness of Computer-Assisted Learning:  
A case study of The Learning Equation.

by


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### ABSTRACT

This study examined the effectiveness of "The Learning Equation" (TLE) software for grade nine Mathematics. The data were collected through interviews with seven students in a public school, their teacher, two teachers from a distance education agency, a student from the distance learning agency, a parent and two teachers who successfully implemented TLE in their classrooms. The study examined the factors involved in the successful implementation of this CAI software, examined how the software matches current design recommendations, and relates that to different cognitive styles and learner abilities. Students were given an opportunity to voice their opinion of TLE and compare it to the usual classroom lessons. The effects of TLE on morale and attitude towards Mathematics for the students in this case study were also investigated.

The study revealed that success with TLE depends on its proper implementation. The teachers interviewed who successfully implemented the program insisted that it was a worthwhile effort. Although interviewed students enjoyed learning using TLE, they still reported a preference for being taught by a teacher. The high rate of transfer from TLE programs to regular classrooms appears to support this claim. Final grades, as reported by students and teachers, did not improve while using TLE. Although TLE appears to technically match recommended design principles, it appears best suited for self-motivated, self-selected students who are average or above average sequential learners.

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## Table of Contents

	<b><u>Page</u></b>
Abstract	ii
Table of Contents	iv
<b>Chapter One: Introduction</b>	<b>1</b>
National Council of Teachers of Mathematics	5
Introduction to the Learning Equation	7
Implementation of TLE in 1997	8
Objectives of the Study	10
<b>Chapter Two: Review of the Literature</b>	<b>11</b>
Introduction	11
Different Uses of Computers in Schools	11
Recent Research into Effectiveness of Computers in Classrooms	17
Students with Outstanding Capabilities	23
Cognitive Style and the Design of Computer Aided Instructions	24
About Learning Theories and Design of Multi-Media Course Ware	30
Research on the Learning Equation	31
Chapter Summary	34
<b>Chapter Three: Objectives and Methodology of this Study</b>	<b>35</b>
Objectives of this Study	35
Methodology	36
Limitations of this Study	41
<b>Chapter Four: Presentation of Data</b>	<b>44</b>
Crescent High School	44
Distance Education Users	54
Successful Implementers of TLE	61

	<b><u>Page</u></b>
<b>Chapter Five: Data Analysis and Findings</b>	67
The Importance of the Teacher	67
Importance of the Teacher and Implementation of the Program	68
Importance of the Design of Software	73
Different Cognitive Styles and Design of Software	79
Students with Outstanding Capabilities	83
Students' Morale and Attitude	85
Other Skills Acquired by Students	86
Administrative Support, Teacher Determination, Success of TLE	89
Student Achievement	89
Geographical Locations	91
<b>Chapter Six: Conclusions and Recommendations</b>	93
Implications Related to the Design of TLE	93
Implications for Teachers	94
Implications for Implementation of TLE	95
Implications for Students and the Community	96
Recommendations for Further Studies	97
Other Recommendations	98
Bibliography	100
Appendices	105

## Chapter 1: Introduction

The digital media revolution has transformed our lives. Computers can be found in our homes, in the work place, in schools and in factories. Digital media equipment such as the video recorder, digital camera and video games are increasingly being linked to a huge worldwide network commonly known as the Internet. It will only be a matter of time before advances in virtual reality create images so real, we cannot tell the difference. The emerging digital economy relies heavily on technology and is quickly transforming business practices.

Children of today are exposed to digital media; they are more knowledgeable and literate. Don Tapscott, (1996) in his book Growing up digital calls this generation of children aged zero to twenty the net generation or simply N-geners. Educating and parenting N-geners is a challenge to adults. Due to the emergence of the global digital economy, information technology becomes associated with economic success and societal well being; growing up not digital will put children at a disadvantage. Nations must ensure that all school children have equal access to computers and the Internet. In a June 1996 address to the American public, US President Bill Clinton spoke about America's plan to meet the technology challenge. His speech entitled, "Getting America's Students Ready for the 21<sup>st</sup> Century: Meeting the Technology Literacy Challenge" created an impetus to computerize schools, not only in the USA but also in many countries around the world.

We know purely and simply, that every child must have access to a computer, must understand it, must have access to good software and good teachers and to the Internet, so that every person will have the opportunity to make the most of his or her own life.

President Clinton (US Dept of Education, 1996)

Computer literacy is not optional because most employers expect all high school and college graduates to have some form of computer literacy training such as word processing and knowledge of databases and spreadsheets. Graduates should also know how to use the Internet.

In 1993, the provincial government of B.C formed a twenty three member Provincial Advisory Committee on Education Technology [PACET] to study the state of technology in B.C. schools and make recommendations for a school technology plan for the next five years. According to the report of this study, primary and secondary schools in British Columbia would soon have approximately 76 000 computers, with a computer to student ratio of 1:8. (Ministry of Education, 1995).The provincial average was 6.5 students per computer but this varied between school districts and between schools within the districts. Most secondary schools had local area networks while about half of all primary schools had networks. The Community Learning Network was a province wide network providing Internet access to all public schools and other on-line services. The Provincial Learning Network or PLNet when completed in

July 2000 will connect 59 school districts (1700 schools), 22 post-secondary colleges, institutes and agencies (112 campuses), public libraries, and non-profit cultural and scientific organizations in British Columbia. It will facilitate distance education, interactive on-line activities, professional sharing and support networks and improve administration efficiency. PLNet was predicted to cost the provincial government \$123 million.

In the spring of 1995, PACET published a report on its study. The paper entitled "Provincial Information and Computer Technology Plan" outlined recommendations to the Ministry of Education addressing the implementation of new media and information technologies in the British Columbia public education system. This report gave ten areas of recommendations. Based on this report, the Ministry of Education of British Columbia introduced changes in curriculum and proposed a \$100 million, five year (1995-2000) school technology plan. The proposed goals were:

1. All students should be provided with computer access.
2. Each student should have equal access to computers. The targeted ratio was one computer for every three secondary school students and one computer to every six primary school students.
3. In addition to teaching computer and media literacy, computers were to be used as instructional support in all areas of the curriculum. The computer was to become a tool that students used to acquire knowledge and solve problems in all subject areas.

4. The Ministry of Education hoped that teachers would be trained in software applications and the integration of technology with new teaching strategies.
5. The province would support districts in technology planning, providing hardware and software standards, facilitating upgrades and network access. The provincial government had established agreements with software vendors to obtain a “best value” for software, hardware purchases and equipment maintenance. There was to be an equitable distribution of funds and the Ministry of Education would work with business and education partners to share costs. The Ministry of Education would continue its program to develop provincial licensing of multi-media and video, which enables schools to acquire software at low prices. It would continue to support partnerships with publishers to develop educational software and new media resources.

Prior to the signing of the Western Canadian Protocol (WCP) agreement for collaboration in basic education in December 1993, the above goals could not be achieved. Very few resource publishers are willing to supply resources catering exclusively to the BC curriculum. Fragmentation of the Canadian education market with variations in curriculum between provinces make it unprofitable for publishers to produce materials exclusively for one province. In 1992-1993, Ontario had a total of 4381 English schools compared to 1893 in

British Columbia. Educational expenditure in Ontario schools, colleges and universities was more than triple that in British Columbia making Ontario a more attractive market for educational publishers. Schools in the western provinces often had to use teaching resources produced for the Ontario school curriculum. To address this issue, the provinces of British Columbia, Alberta, Saskatchewan, Manitoba, Yukon Territory and the North West Territories agreed to work together to form a common curriculum framework with learning outcomes in mathematics, language arts and international languages. The first common framework in mathematics, Kindergarten to Grade 9, was released in English and French in June 1995. With a larger market size, publishers, computer vendors and other resource suppliers are willing to customize products exclusively to fit the common curriculum of these provinces. The Learning Equation, the multi-media computer aided instructional software under study in this project, is one example of a successful partnerships between the western Canadian provinces and a publisher to develop educational software and new media resources.

#### The National Council of Teachers of Mathematics (NCTM)

The National Council of Teachers of Mathematics (NCTM, [www.nctm.org](http://www.nctm.org)), founded in 1920, has a membership of 110 000. It is the professional association for mathematics educators in the USA and Canada. The NCTM published a document known as the Curriculum and Evaluation

Standards for School Mathematics in 1989. The document was revised and released in draft form in October 1998. It covered a set of specific standards to outline curricular changes for mathematics education in the information age. The NCTM perceives mathematics as an active and investigative subject. It emphasized problem solving, reasoning, communication and connecting mathematics with other subjects and the real world. The NCTM seeks to produce self-directed learners who will value and use mathematics to solve real-life problems.

There were many reasons for a need of new goals. One of these reasons is that industrialized countries have experienced a shift from an industrial to an information society. Advances in science and technology added new demands on mathematics education as mathematics is applied in these areas. Hence, this shift changed the aspects of mathematics that need to be transmitted to students and the concepts and procedures they must master if they are to be self-fulfilled, productive citizens in the next century. In its recommendations for teaching practices, NCTM expected that teachers would cater to individual differences in students so as to encourage continued study of mathematics by all students. Diversity includes gender, culture, ethnicity, socioeconomic background, language, special needs and mathematical learning styles. Moreover, teachers of mathematics are also expected to use appropriate technology to support learning. Technology includes computers and computer software, calculators, interactive television, distance learning, electronic information resources and a variety of relevant multi-media. The

partnership between the Western Canadian Province and publishers to develop educational software and new media resources is in line with the new goals of the NCTM.

### Introduction to "The Learning Equation"

The Learning Equation, commonly called TLE, is a computer guided learning courseware developed by Nelson Thomson Learning Canada and the Canadian Western Provinces and Territories. The first set of four CDs was released in 1997 for grade nine Math students. In that year over 250 schools in Western Canada used the software with over 9000 students (ITP Nelson, 1998). In the 1998/99 school year, over 25000 students used TLE. Written by 100 Canadian mathematics teachers with 200 hours of authoring work per lesson, the CDs for grades 7,8,9 and 10 cost the company \$7 million to publish. The provinces guaranteed use of the resource. In British Columbia, the provincial government bought a provincial license to use the software and schools can buy it at a discount. The company hoped that over a period of time, it would recover its initial investment. They planned to also market the product outside Canada.

The original grade nine series was refined in 1998 using feedback received from teachers and students. TLE is supported by print resource materials for students, teachers and teacher in service training. The software covers the full Canadian mathematics curriculum. It was designed to assist in the delivery of the Common Curriculum Framework (CCF) of outcomes in

mathematics as prepared through the Western Canadian Protocol for Collaboration in Basic Education (1999). The software is compliant with the recommendations of the National Council of Teachers of Mathematics Curriculum and Evaluation Standards for school mathematics. The primary objective was to develop math resources which improve student performance and retention of expected math outcomes. Another goal was to assist educators in the transition to effectively integrating technology into their instruction.

### The Implementation of TLE in 1997

The grade nine Learning Equation multi-media courseware was initially intended to be used as the main mode of instruction. It contained the full mathematics curriculum. In the 1997/98 school year teachers who volunteered to use the software attended a four days training session on how to use and implement the software. During that school year, more than 250 schools in Western Canada used the software. In these pioneering schools students were given a copy of the software on CDs and they went through the lessons on their own. The program was to do all the teaching; no classroom teaching or textbook was required. During math lessons students would work at the program while the teacher acted as facilitator or coach. Students did the exercises on the CD-ROMs which could be taken home. The first version of the CDs did not have progress tracking functionality. It was also not linked to the www. The new version released in 1998 includes such features. The progress-tracking feature captures information such as how many pages or screens the

student visited for a particular section. It tracks the number of questions attempted by the students and records the marks obtained for self-checks. Students are encouraged to make lesson notes as they progress in the lessons. Teachers can collect these notes.

In the 1998/99 school year, many schools in British Columbia modified the implementation and use of The Learning Equation while other schools went back to traditional classroom teaching. Today, there are many different ways in which the software is used. Schools may continue to use it as the main mode of instruction or it may be used as enrichment or a complement to the usual classroom teaching. Other schools may use it as the main mode of instruction but give students an option to attend normal classroom lessons if they cannot learn successfully with the software. Distance education schools use it in their distance education program. The usage of this software is varied and certainly different from what was originally intended. Some schools are more successful in adopting this multi-media teaching strategy than others. The teachers found out that the basic function of teaching cannot be left entirely to a software program.

## Objectives of the Study

The objectives of this qualitative study were to answer questions in the following areas:

1. From the community's standpoint, is the large amount of money spent on the use of computers producing desired results?
2. From the standpoint of students, is computer-mediated learning any different from traditional classroom lessons?
3. From the teacher's standpoint, is it worth the effort to incorporate the use of technology in their classrooms and curriculum? The study also looked at how teaching strategies can be adapted with technology.
4. How does the design of TLE relate to students' preferred mode of learning and level of ability?

## Chapter 2: Review of literature

### Introduction

This Chapter contains seven sections. The first section looks at the various uses of computers in the classroom. The second section reviews some recent research into the effectiveness of computers in the classroom and the third discusses the use of technology and students' with outstanding capabilities (SWOC). The fourth section reviews literature on cognitive style and the design of computer aided instructions. The fifth section looks at learning theories and the design of multi-media courseware. The sixth section summarizes research done on "The Learning Equation" and the seventh section is a summary of the key points of the chapter.

### Different Uses of Computers in Schools

One of the many ways that computers can be used in education is for Computer Assisted Instruction (CAI) also known as Computer Guided Learning (CGL). Besides CAI, computers can be used in educational management while the Internet is used for communications and research. Since TLE software is used as CAI, this study focuses on CAI as a mode of computer use. Under CAI, there are different approaches to instruction: drill and practice, tutorial, simulation and multi-media instruction. A more recent development is the use of networking and conferencing technology to facilitate collaborative group projects and communication. Teacher centered instructions must take into

consideration student centered learning. The students use computers as an information tool, for text and graphics presentations, processing of information and as a multi-media learning tool.

Despite many criticisms (Forcier, 1996), the teaching strategy of drill and practice is still used in many schools around the world. Drill and practice can be used to reinforce instruction and commit the learned concepts to long term memory. Good computer software can be used for this purpose. It can motivate students who might not have found other media forms engaging. Drill and practice develops fluency of an existing skill needed to advance to the next level. Prior to the use of any drill and practice sessions, it is assumed that students have been taught the concepts and procedures. Behaviorist teachers, who tend to emphasize on practice and students' test grades would select the appropriate software which meets the lesson objectives, monitors student progress and assesses performance. Constructivist teachers emphasize teaching the understanding of concepts. After teaching the concepts, these teachers could use drill and practice to reinforce learned concepts. Students can interact with the computer by typing in text fields or moving objects on the screen. As they work the problems, they apply learned concepts in a meaningful way. Effective software requires the students to respond based on deductions and inferences as well as recall (Newby, Stepich, Lehman, & Russell, 1996). Drill and practice software usually places emphasis in tracking student performance (Newby, Stepich, Lehman, & Russell, 1996).

There are two types of tutorial programs: linear and branching (Forcier, 1996). Both types of tutorial software provide students with the topic overview and then present questions that lead towards the learning objective. Tutorial programs often include placement tests. Students first take a pretest to determine their readiness for the materials to be covered; then they are presented with the information and questions. A linear program does not branch into a different level of difficulty. Other programs have branching capabilities to cater to different categories of student ability. Like drill and practice, tutorials keep track of student progress. As with the drill and practice software, this type of program can be used by both behaviorist and constructivist teachers. Unlike the drill and practice software, tutorial software caters to different student abilities. A disadvantage with tutorial programs is that they may be intimidating because they start with a test. Also, students may lose interest if the program is used all the time.

Kulik (1994), in a meta-analysis of 97 studies of findings on computer based instruction, found an average effect size (ES) of 0.38 for software classified as drill and practice and tutorial. Effect size is the standardized difference between the experimental and control groups. An ES of 0.38 means that the technology based instruction is thirty eight percent more effective than the control group instruction. In his study, Kulik determined that an effect size of thirty eight percent was significant. The word "effectiveness", as defined by Kulik in the study, compared student achievement, impact on learner self-concept and attitudes, and effects on interactions in the learning environment.

Simulation is another teaching strategy which can be made more effective with the aid of a computer. Simulation can be used to reinforce learning by providing an environment for active discovery learning where students can test the effects of changing variables. Simulation software can also test newly learned concepts and skills. For example, a simple spreadsheet program lets students manipulate and analyze data. Another very well-known simulation program is the software program Calculus produced by Broderbund (Forcier, 1996). As different values of  $x$  are entered, the value of  $f(x)$  is calculated.  $F(x)$  can also be plotted for different  $x$  values and for different powers of  $x$ . Sine, cosine and other trigonometric graphs can be plotted. Students can be asked to "predict" the outcome and check if they are correct. They make the decisions and see the results. Another simulation software created by researchers from Dartmouth Massachusetts allows students to test the concept of velocity. James Kaput, a mathematics professor who led this development, said that the most powerful use of a computer is its ability to make abstract concepts visual (Wengliniski, 1998). Other award winning simulation software like the Oregon Trail can easily capture student interest, keeping them at the computer for hours working at a simulated real world problem (Forcier, 1996).

Simulation software is highly constructivist. In his article "Can Technology Help Teach for Understanding?", Nickerson (1995) wrote about the power of microworld simulations in correcting misconceptions. Microworlds are graphically oriented software that can be used to simulate how the real world

works. They are used to facilitate learning in areas such as mechanics, physics and electricity. Such simulations help learners see how their own understanding differs from valid principles. Nickerson cautioned that simulations should not be pressed too far because a simulation of a process is one way in which it can occur but it is by no means certain the simulation is the only possible outcome.

One disadvantage of simulation software is that it usually does not cover the whole curriculum. Simulation software is also scarce because it is expensive to produce.

Interactive multi-media is a relatively new development and the technology is still evolving towards a greater link to the Internet. Multi-media employs more than one way of communicating information to the users. It uses audio sound, video, animations, still graphics, photographs and text. Multi-media brings material to life, enhancing students' ability to remember and understand what they see and hear. It is an extension of simulation with options for drill and practice, tutorial and problem-solving approaches. Multi-media programs are often a combination of all the above. Hence, such software does not usually follow strictly one particular learning theory. Information is usually stored on either CD-ROMs or DVDs. Macromedia asserts that interactive multimedia software made with Macromedia Director is fully web friendly (<http://www.macromedia.com/software/director/productinfo/features/newfeatures/>).

Apple Computer's HyperCard, Roger Wagner's Hyper Studio and Macromedia's Director K-12 offer students an opportunity to create their own multi-media projects. These programs give the user control over powerful tools in the

exploration and creation of information. For example, a history project can be made with Hyper Studio complete with animations, audio, text and graphics. Students will have to work out the navigation of their project and in the process develop problem solving skills. Studies show that students work harder and longer hours when using the computer for projects (Means & Olson, 1995; Dede, 1998). Students' morale and attitudes toward their work are improved. Their projects can be burned on CD-ROMs as a permanent record of their work. Teachers can also use the software to prepare interactive lessons. The Learning Equation is such a multi-media, computer guided learning software.

One of the most powerful features of computers is their ability to network. Network technology allows teachers and students to communicate and share information with peers from all over the world thus breaking the isolation in their classrooms. Students from Canada can communicate and share information with students from countries like Australia, doing things such as exchanging information on weather, history, geography or simply chatting. Learning becomes meaningful and real. With advances in conferencing technology, students and teachers can see and hear each other live. This facilitates group work and live discussions. Lessons can be published on the Internet. All these developments have huge implications for schools, distance education, special needs students and institutes of higher learning.

## Some Recent Research into the Effectiveness of Computers in the Classroom

It has been twenty years since the computer was introduced into public schools and billions of dollars of taxpayers' money have been invested in these machines. There must be fiscal accountability as to whether technology is in fact effective. Software manufacturers often want to know if their products are meeting user needs and expectations. They need such information for future planning and investment decisions. The effectiveness of multi-media CAI in education is difficult to measure because of the many ways in which computers can be used. Researchers have defined the word effectiveness to include positive outcomes such as improved test scores, increased student learning abilities, comprehension, motivation, attitude, strong student, parent and teacher support, improved student attendance, improved student retention, improved job placement and improved teacher satisfaction. It has been found that traditional ways of assessing the effectiveness of educational programs are deficient for assessing the contribution of computer technology (Glennan and Melmed, 1996).

New research on technology's effectiveness in teaching appears to confirm what many educators have optimistically suspected: Computers can raise student mathematics achievement and improve the school's climate. However, they have to be used and implemented properly. These are the findings of Wenglinsky (1998), an associate research scientist at the Princeton, N.J.-based Education Testing Service who carried out an analysis for Education

Week. When used for the wrong purpose or if a technology program is not implemented properly, computers can do more harm than good. The benefits of technology depend on how the technology is used. Wenglinsky's study was based on the performance of fourth and eighth graders who took the 1996 National Assessment of Educational Progress test (NAEP) for mathematics. Wenglinsky found strong links between certain kinds of technology use, higher test scores and improved school climate. It was found that eighth graders whose teachers used simulation software to encourage higher order thinking and problem solving did better on the NAEP when compared to those students whose teachers did not use such software. Eighth graders whose teachers used computers for drill and practice purposes did worse than those students whose teachers did not use such software. Teacher training in the use of technology resulted in 35% of a grade level gain in scores. Simulation software and applications resulted in a 42% gain in score while drill and practice showed negative returns.

The teacher is the key to determining the impact of an innovation. More attention should be placed on professional training and the quality and length of such training. There is also indication of a better school climate, higher morale and lower absenteeism rates. Students like using computers because they provide instantaneous nonjudgmental feedback. They can work at their own pace and are neither held back nor left behind by their peers. Nickerson's (1995) article "Can Technology Teach For Understanding" which is published in the book Software Goes To School wrote that CAIs provide a supportive

environment. Ironically, while computers can be intimidating, they can also be comfortingly impersonal. Students who are reluctant to reveal their ignorance for fear of ridicule or rebuff will find the computer non-threatening. Students are motivated by well-designed educational games. Wenglinsky's (1998) study did not cover the possibility that such educational gains could be achieved by other educational tools which may cost less. Moreover, it did not explain how and for what purpose the drill and practice exercises were implemented. The findings and report appear decidedly set to dismiss drill and practice as grossly deficient and simulation software as highly credible.

A study done by Glennan and Melmed (1996) also showed that when properly implemented, technology can generate better test scores, improved student attitude, enthusiasm and engagement. Successful schools use computer technology to tailor learning according to learner needs and abilities. Students have access to resources and expertise outside school hours. Teachers are able to manage and guide the learning activities of the students. Glennan and Melmed cited Kulik's (1994) meta analysis of studies done on computer based instruction. Kulik's findings appear creditable. Based in eight different locations, his research teams aggregated over five hundred individual research findings involving the effectiveness of computer based instruction. Kulik concluded: (1) Students learn more in classes with computer based instruction; (2) Students learn the lessons in less time; (3) Students like their lessons more when using computer based instructions; (4) Students develop positive attitudes; (5) The average effect of computer based instruction on

attitude toward subject area was near zero for 34 of the studies. This last finding suggests that positive effects in one area may not mean similar effects in another area.

Another noteworthy study is a US department of education-funded study of nine technology rich schools. Means and Olson (1995) found educational gains for all students regardless of age, race and social economic background. They focused their research from another angle to look at how technology fosters constructivist teaching.

Apple Computer's report on ten-years of ACOT research provided evidence that technology rich environments resulted in better student scores on standardized tests. (Glennan & Melmed, 1996; Software Publishers Association, 1997). Moreover students also developed the ability to explore and represent information in many forms; became socially aware and more confident; communicated effectively about complex processes; became independent learners and self starters; knew their areas of expertise and shared that expertise spontaneously. In essence, these are characteristics of the N-geners mentioned in Tapscott's book Growing up Digital (1996).

All these successes did not come by simply adopting technology into the classroom. Studies by Glennan and Melmed (1996) examining the success of technology-rich schools revealed four key features. First, there is careful planning among school leaders, teachers, parents and students. There is a determination to use technology in a "learner centered" environment. Technology is used to support students' individual needs and capabilities. Level

of family involvement also played a part. Secondly, success is not measured simply in terms of student grades but also in the drop out rate, job placement, level of family involvement and attendance. The third feature emphasizes restructuring the school to support this learner-centered environment facilitated by technology. Physical restructuring of the classroom or computer laboratories is an important factor in the success of technology rich schools. Partnerships are built among teachers, administrators, parents and students. Lesson schedules and duration may need to be adjusted. The fourth feature is that students have almost universal access to computers, at least one computer to every five students. These schools invest about five times more on computer hardware and software than other schools. It is clear from these findings that the successful use of computers in schools requires a commitment to computer technology from school management, leaders, administrators, parents, teachers and students.

The use of multi-media instructional software requires teachers to give up the traditional lecture style mode of instruction. The teacher becomes more like a “facilitator” or “coach” instead of the “sage on the stage”. Paradigms have to shift from broadcast learning to interactive learning. Teachers are responsible for creating a structure where students work both individually and as a group. Teachers also need to arrange for access to facilities, equipment and resources. Once lessons begin, the teacher no longer has total control over the different learning pathways taken by individual students. Students are in control of their own learning. Teachers make suggestions, answer student questions

and encourage students to think about and listen to the views of others. In the study done by Means and Olson (1995), it was reported that in the early stages of technology implementation, the teacher's job becomes harder. Technical demands are only part of the problem. Teachers have to adapt the technology to meet the needs of individual students. This often means that they have to know their subject areas and the curriculum well. They take on the role as team builder and coach, guiding students in the meaning making process. Diagnostic skills are important. Teachers must know how to monitor students' progress and when to intervene if intervention is required. Intervention at an early stage of students' work may deprive them of the opportunity to discover learning on their own. Teachers have to function as leaders and be flexible in their teaching approaches. More time is needed for them to plan and prepare lessons.

Means and Olson (1995) wrote that the initial predictions that technology will make a teacher's job easier are naïve. In fact, teachers contemplating the use of technology may well have to ask themselves if it is worth all the effort. This leads to the question of cost-effectiveness of using computer-based instruction. Can similar results be reached by a less expensive and easier way? Fletcher, Hawley and Piele (1990) did a most interesting study on this question. They compared the costs of additional tutoring, reduced class size, increased instruction time and computer based-instruction required to obtain comparable gains in outcomes. CBL was substantially less expensive than all the other approaches with the exception of tutoring by peers. Computer prices have since fallen. Means and Olson (1995) found that teachers who have successfully

integrated the use of technology into their classroom activities and curriculum all said that the extra hard work is worth the trouble.

A point to note would be that researchers such as Means, Olson, Melmed and others mentioned above selected suitable technology-rich schools to conduct their research. They reported difficulty in finding suitable schools implying that such schools are rare (Means & Olson, 1995; Glennan & Melmed, 1996). The magnitude of change required for a school to incorporate technology-supported teaching and learning is great. In the ACOT study, Apple Inc provided teachers and students with computers to work with. Their findings are not different from the other large meta-analysis studies done by Fletcher-Flinn and Gravatt (1995) and Ryan (1991). Evidence from these studies show that when implemented properly, computer based instructional programs improve the quality of learning and schooling. The producers of the TLE program have emphasized that the key to the success of TLE depends on effective implementation practices.

### Students With Outstanding Capabilities. (SWOC)

Some schools in British Columbia have special programs for students with outstanding capabilities. Schools in many parts of the world, including the United States, have formal gifted programs with a separate curriculum. In this study, the term SWOC will be used instead of gifted. These students have special needs. Computer technology is becoming increasingly important for them. SWOC students are typically not ideal candidates for drill and practice (Kanevsky, 1985). They prefer instructional techniques which permit maximum exploration of a topic. They want to know 'why' things work the way they do.

Multimedia simulation software focuses on higher level cognitive processing. SWOC students like to take charge of their own learning. With CGL software, they can select the relevant topic or sections to explore and investigate. They can progress at their own pace. It is predicted that in the new millenium, more SWOC students will take courses via distance using conferencing technologies, television and computer software (Shaughnessy, Jausovec & Lehtonen, 1997). In this way, they can accumulate credits for college in their spare time. Some formal gifted programs offer courses in computer programming. Students are put in charge of telling the machine what to do. They are given the opportunity to practice problem solving skills, creativity and reasoning.

#### Cognitive Style and the Design of Computer Aided Instructions

Cognitive style is an individual's preferred habitual approach to organizing and representing information. Ross and Schultz (1999) used the Gregorc style delineator to classify learners into four types: CS, AS, AR, CR. People in the Concrete Sequential (CS) category are linear sequential learners. They are highly organized and prefer a quiet and structured environment. They usually like to be told what to do and do not go against the norm. People in the Abstract Sequential (AS) category are evaluative, analytic and logical. They like learning in an orderly and quiet environment. Abstract Random (AR) individuals focus on emotions and are people oriented. Learning is non-linear and multi-dimensional. They learn by building relationships with other people. Concrete

Random (CR) individuals like to explore. They are divergent thinkers who prefer a competitive environment. They do not need many details to solve problems.

Learners do not belong strictly to one particular category. CAI might not be the preferred learning mode of some students. Most older software are an extension of the sequential learner's mind and hence suitable for the CS and AS learners. Hoffman and Waters (1982) cited by Ross and Schultz (1999) in their article "Can computer-aided instruction accommodate all learners equally?" concluded that CAI is suitable for learners who can continue to stay along one track until completion. More recent multi-media simulation software and the Internet hyperlinks do cater to non-linear learners with the flexibility to explore various sections of the program at anytime. However, this could result in some students skipping important content when it is necessary to proceed step by step. Castelli et al (1996) cited by Ross and Schultz (1999) discovered that many hypermedia users get lost in hyperspace. Unlike teachers who can analyze misconceptions and modify teaching style to suit individual students, a machine requires the learners to harmonize and adapt to its programming in order to attain the learning goals. Hence, if the learning style of a student is not the same as the teaching style of the program, the learning medium becomes invasive and inappropriate resulting in these students being left behind. In order for large-scale CAI lessons to be successful, teacher mediation becomes important.

Riding and Rayner (1998, chapter 2) cited by Riding and Grimley (1999) summarized learning style into two dimensions: the wholist-analytic and the

verbal-imagery. In the wholist-analytic dimension, the wholist learns in wholes while the analytic learns in parts. In the verbal-imagery dimension, the verbal learns by verbalizing and imagery learns by pictorial representation. A learner can be a wholist-verbalizer, wholist-imager, analytic-verbalizer or analytic-imager. Riding and Grimley (1999) found that wholists learned better with multi-media presentations. Modes of multi-media software presentation used in the study included picture and sound, picture and text and picture, text and sound. All these findings imply that the design of the software and learner preference is important.

Clariana (1997) reported his study concerning the shift in learning style due to the use of CAI. He found that learners become more active, less reflective and tend to become convergent rather than divergent thinkers. The navigational design of some programs reward students who guess the answers. Thus some learners might key in the wrong answer, press enter, hoping that the feedback would provide meaning to their misunderstanding. Although this increases instructional risk that some students might be too eager to move on with the program, it is helpful in encouraging very weak and passive students to work at the subject.

The design of TLE has attempted to minimize such concerns. In TLE, students work through each module in a sequential way. Within a particular section in a main module, students can proceed to the next screen only if they correctly fill in the blanks on that screen. There are blanks in almost every screen or page. Students are given three tries before the answer is revealed.

Each incorrect response brings up a message guiding students to the right answer. Students can page back to the previous screen but will have to fill in the blanks again before they can proceed. Hence, if a student is at the second last screen of a particular section and wishes to go back to an earlier page to look up some information, he can do so. However, from that earlier page, he would have to fill in all the blanks again until he reaches the last page. This is true for every section in the software including the exercises, tutorial and problem sections. The color of the buttons change when a particular section has been successfully completed.

Reporting on the effectiveness of technology in schools (1990-1997), the Software Publishers Association (SPA) reported that in addition to embedding cognitive theory into the software, other design characteristics are also important (Fletcher-Flinn & Gravatt, 1995). These characteristics include type of software, instructional control, type of feedback, embedding of strategies for conceptual change, scaffolding of learner support, still graphics, animation, video, navigation techniques, texts, games and window presentation style. This report is based on 219 research reviews. Its purpose was to provide the software publishers with information on the type of software which schools find useful. It cited Wood's (1991) research, "An investigation of the effects of tutorial and tool applications of computer based education on achievement and attitude in secondary mathematics" stating that the best choice of software type might depend on instructional goals. For example, tutorial and drill and practice software can improve computational skills. If understanding of concepts is the

key goal, simulation and tool software are more appropriate. Some software is developed with the key purpose of improving problem solving ability.

Evidence also suggested that the effectiveness of software was dependent upon the subject area, characteristics of student population, role of the teacher, student group, the design of the software and the level of access to the technology. The SPA study (1997) reported that learners using self-paced or learner controlled software performed better than those using program-paced software. However, for low-ability students and students with little prior content knowledge, user controlled software should be used with caution.

Concerning feedback, the report studied the effectiveness of what it termed AUC feedback and KCR feedback. AUC stands for answer-until-correct. A typical AUC feedback would be "No, try again." KCR stands for knowledge-of-correct-response. This type of feedback provides the correct answer with explanatory notes after one attempt. Slow learners performed better using KCR because they were provided with information to clarify the misunderstanding. The SPA report (1997) did not discuss the performance of average and above average students with regard to feedback. Schwier and Misanchuk (1993) wrote in their book *Interactive Multimedia* that feedback should be appropriate, in plain language and to the point. It can be in the form of text or audio. Clariana (1993) wrote about student performance record and feedback in an article "The motivational effect of advisement on attendance and achievement in computer based instructions." He found that feedback in the form of a progress report is helpful. The report should provide information concerning time spent on each

activity, activities completed and the percentage correct for each activity. The new version of TLE, released in 1998, keeps track of how many times a section is visited. This version was released one year after the implementation of the original version. Teachers can monitor students' progress and completion of lessons through a tracking application. If the school laboratories are networked, records can be generated, updated or added each time a student logs on. Information is securely kept on the server and teachers have official access at any time. In a non-networked environment, information can be stored on floppy disks. Appendix A shows a sample of what a typical student report looks like.

### About Learning Theories and the Design of Multi-Media Course Ware.

Wild and Quinn (1998), in their article "Implications of educational theory for the design of instructional multi-media" suggested that rather than debate which theory is credible and adopting that theory for the design of multi-media software, learning theories should be taken as a whole. A combination of unique and opposing attributes of the various theories is more useful than a linear path connecting extreme theories. Schwier and Misanchuk (1993), in their book Interactive Multimedia Instructions, are not willing to adopt one single theory for the design of multi-media instructions. Students have different learning styles and needs. An unmotivated learner may respond well to a high degree of reactive interaction during instruction while a motivated learner prefers an open-ended strategy. The nature of some subjects and lesson objectives may require a thorough set of drills, while others may require simulative approaches. Multi-media systems are capable of storing large quantities of information. It is better to adopt more than one cognitive orientation so as to cater to different learning objectives, learner preferences and learning styles.

TLE is a linear program where students have to proceed step by step. Each lesson module consists of the following sections: introduction, lesson, examples, practice and problems, and test or self-check. Each grade level consists of 45 to 60 lessons. The practice and problems section of each lesson consists of 25 questions based on the lesson concepts. Questions are arranged in increasing level of difficulty. The test section, also known as "Self-Check",

consists of up to ten questions per lesson. Students can review each question and their own answer, see a complete solution, or try another question of that type. Results are recorded and students must achieve seventy percent to register a completion.

There is a teacher's manual and a student's refresher with extra practice questions. Hence, TLE provides students with sufficient practice questions and which can be used for drill and practice purposes. Students are required to construct their own understanding of the concept as they proceed from screen to screen answering the questions. The questions are designed to probe higher order thinking skills required for problem solving. TLE also has simulations to teach for understanding and demonstrate mathematical proofs. Thus, the program can be highly interactive and constructivist.

The program is supported by a web-site and a list serve where teachers using TLE can exchange ideas. The design of TLE does reflect many recommended principals of instructional design.

### Research on The Learning Equation

In the 1997/98 school year, ITP Nelson Canada commissioned an independent consultant, Psychometrics Canada Ltd., to evaluate the newly developed TLE program used in grade nine classrooms in Alberta and British Columbia (Fitzsimmons & MacNab, 1997). Eight TLE schools with a total of 611 student participants and eight non-TLE schools with a total of 573 student

participants in Alberta and British Columbia participated in the study. Six out of the eight TLE schools had within school comparison groups. This means that they had both TLE and non-TLE classes and comparisons could be made within the school. Both groups of students, TLE and non-TLE, sat for an achievement test developed by Alberta Education. This achievement test was designed specifically to measure the content of the grade nine math curriculum. Performance of the TLE students was compared with the performance of the non-TLE group. Results were very promising and consistent with the findings that educational software can lead to an improvement in grades. For the overall sample, 21% of TLE group achieved a score of 80% or greater while 14% of the non-TLE group achieved this mark. For the within school comparison group, 19% of the TLE group achieved a score of 80% or higher, while 5% of the non-TLE group achieved this mark. The study only compared grades between the TLE groups and non-TLE groups. It did not study the movement in grades of the students from grade 8 to grade 9 for those on TLE. Thirteen of the teachers (93%) who used TLE completed a questionnaire and overwhelmingly agreed that the program is user friendly, meets the objectives of the curriculum and the support materials are helpful. These findings about teachers' impressions of TLE are not surprising because TLE is very task oriented and technically a good production.

The findings about students' performance on achievement tests are subject to argument. Moreover, the study only looked at student grades on a single exam. Since the evaluation was commissioned by the publisher, it would

be expected to report positive results as this could be used as a marketing strategy. Nevertheless, its findings did not contradict other researchers' findings that CAI can improve students' grades if implemented properly.

The publisher of TLE also commissioned James G. Beatt to conduct a qualitative pilot study in January 1997. The title of the study was "Computer Guided Learning (CGL) and Control Groups". He observed sixteen grade nine classes in four provinces. Ten of the classes were TLE classes while six were control classes. He observed student and teacher behaviors and tried to determine the degree of student motivation. This study reported positive findings in student motivation, behavior and time on task. Learning is maximized when students are assigned to work in pairs. The most efficient classes are those where the teacher allowed the students to work at their own pace. The study also concluded that the use of CGL dramatically changes the role of the teacher.

Both of these large evaluations and studies into the effectiveness of TLE were funded by the publisher. There is a need to conduct non-biased large-scale quantitative and qualitative studies on TLE if the Western Provinces intend to use TLE software on a wider scale.

## Chapter Summary

Computer technology can be applied in many ways to education. Most research shows that if implemented properly, computer aided instruction leads to better grades, improved student attitude, increased time on task and higher teacher morale. Initial implementation of technological changes will increase the teachers' workload. They have to change the way they normally teach to become a "facilitator" or a "guide" instead of the "sage on the stage". They also need to plan group discussions and monitor student progress. CAI however, cannot accommodate all learners equally as some students will find learning with computers difficult. Software design should embed cognitive theories. However, CAI should not adopt one single theory for the design of its instructions. Students have different learning styles and needs and the software must cater to these differences as far as possible.

### Chapter 3: Objectives and Methodology of this Study

#### Objectives of this Study.

Research has been conducted on the effectiveness of TLE. However, these large studies were commissioned by the publisher. They show positive findings in terms of student grades, attitude, time on task, teacher feedback and in fact, the studies did not find anything negative about TLE. There is a need for non-biased studies into the effectiveness of this software if it is to be implemented on a large scale in the Western Provinces.

This qualitative study examined students' perceptions about using the software program TLE as the main mode of instruction in a mathematics course and reports lessons learned by teachers who have used the software. The objectives were to gain insights and answers to questions in the following areas:

1. From the community's standpoint, is the large amount of money spent on the use of computers producing desired results? Hundreds of millions have been spent and more will be spent on technology. In March 1999, the BC Ministry of Education announced a budget reduction. Programs for special needs children are being scaled back and many schools have to cut back on subjects such as music. There was no public mention that multi-million dollar

technology plans will be scaled back. Desired results are defined as student achievement, attitude towards math, motivation and school climate.

2. From the standpoint of students, is computer-mediated learning any different from traditional classroom lessons? The study also attempted to give students a voice on their opinion on software and their views about computer guided instruction or using computers as the main mode of instruction in place of traditional classroom lessons and textbooks. It is interesting to listen to students as they speak about computers and the nature and future of learning. Their voices have to be heard because they are the end users of the product.
3. From the teacher's standpoint, is it worth the effort to incorporate the use of technology in their classrooms and curriculum. The study also looked at how teaching strategies can be adapted with technology.
4. How does the design of TLE relate to students' preferred mode of learning and level of ability?

### Methodology

After the approval to conduct this research project was granted by the University of Victoria's Human Research Ethics Committee (see Appendix B) and the school district offices, the researcher looked for schools which used The Learning Equation as the main mode of instruction. On Vancouver Island one school in Greater Victoria and a distance learning agency in Saanich participated in the study. Another school in Burnaby consented to participate

but approval from the school board could not be granted on time to interview students in the school year 1998/1999. Hence, only the teacher was interviewed. A teacher from North Vancouver who was successful with TLE also consented to participate in the study. The researcher then went to the public school in Greater Victoria to recruit participants for the study. All participants had to sign a consent form, consenting to participate in the study. The student consent form is found in the Appendix C and the teacher consent form is in Appendix D.

Participants were grouped into three sections for reporting purposes: the participants from the large public school in Greater Victoria; the distance learning agency; and the two teachers from the mainland, one from Burnaby and the other from North Vancouver. Interviews were conducted with these three groups of users. Some of the interviews were taped while others were not. In general, student participants were asked to share their experience with the software, state whether they would recommend it to a friend and comment on who in their opinion would benefit most from this kind of teaching arrangement. They were also asked to give suggestions as to improvements or changes they would make in the software. A detailed copy of sample questions asked can be found in Appendix E(student questions) and Appendix F(teacher questions). These student questions were developed with the aim of finding answers to the questions which this study seeks to examine. The questions were tested on the first two student participants from Crescent High School and refined for the other student subjects. The researcher visited the school to talk to the students

about the study. Students who had participated in a TLE classroom the previous school year were asked to volunteer to be interviewed about their experience. Out of the seven students who volunteered, five had successfully completed the program while two had opted to return to the traditional mathematics classroom. The teacher from the TLE classroom and the seven students from the program were designated as the first group of users for reporting purposes.

The interviews were each about an hour long and were held in the school during lunch breaks. The teacher will be known in this study as Jacinth. Crescent High School (not its real name) implemented TLE on a large scale in 1997. Sixty grade nine students were given a set of CD-ROMs and they worked through the materials on their own. Math lessons were conducted in the computer labs, with each lab session lasting for one hour and twenty minutes. There were two lab sessions per week. Some students stayed back after school hours to work at the software. Every student had a computer to work with during class time. There was no traditional classroom teaching and no group work. Students were also permitted to bring the CDs home. However, any students without a computer at home who chose to participate in the program had to finish their work in school. The teacher acted as the facilitator during math classes. Jacinth mentioned that she had difficulties getting enough computers for all the students. Students had to make lesson notes and hand in their notes and report sheets. The report sheet kept a record of which topics a student had completed. Students filled in the report themselves. By the end of that school

year, only 25 students were still on the program. The others had gone back to using their textbooks and traditional classroom lessons. Of those who stayed on the program, some used both the textbook as supplement. Due to school transfers, only 25 out of the original 60 students who used the software remained with the school during the time of data collection in June of 1999. The students interviewed were in grade 10 at the time of the interview. TLE was no longer in use. The seven students who volunteered for interviews were given pseudonyms. These are: Jasper, Chalcedony, Sardonyx, Carnelian, Chrysolite, Beryl and Topaz.

The second set of interview data was collected from a distance education school. One student and two teachers were interviewed. The teachers will be known as Emerald and Sapphire. The interviews with the teachers took one hour each and they were conducted in the school. Sapphire used TLE in 1997-1998 while Emerald used it in 1998-1999. Both were pilot projects to experiment with TLE as applied to distance education. Students in the distance learning agency go through TLE on their own at home. The student interviewed was a student with outstanding capabilities, scoring 'A's for almost all his subjects throughout his school years. He was attending grade seven in a public school at the time of the interview but he had successfully completed the grade 10 TLE with the distance education agency. He scored an 'A' grade for both his grade 9 and 10 mathematics courses taken through the distance learning agency. He used TLE as a mode for academic acceleration. Nevertheless, he still belongs to the public school system and enjoys playing

soccer with his friends, implying that he gets along well with his peers in school. He did not want to transfer to another school with a SWOC program because he wanted to be with his friends. This student will be known as Jade. The student's father, who played an important role in coaching his son in using TLE at home, was also interviewed. He will be known as Diamond. Both Jade and Diamond were interviewed in their home and the interview lasted for an hour.

The third set of interview data was collected from two teachers who had successfully implemented TLE in their schools. These two teachers are from Vancouver and Burnaby. One of the teachers, Ruby, is now working for Nelson Canada and the BC Ministry of Education. Ruby is the representative for The Learning Equation in the province of BC and was one of the content editors for the program. The other teacher will be known as Pearl. Both interviews took about an hour each. The interview with Ruby took place on the University of Victoria campus. Although Ruby was working for the publisher, he was very objective when giving his comments on TLE. He reported the negative facts as they are. As a former school teacher who had successfully implemented TLE, he was aware that students in several schools were opting out of the program and he admitted that the use of TLE is far from what the publishers had originally intended it to be. Pearl has been using TLE as his main teaching mode since it was first introduced in 1997. He first implemented the program following guidelines recommended by the publishers in 1997. All his students in two classes had to adopt this mode of learning, which was basically the same as that implemented in Crescent High School. He had about 65 students on TLE

that year. The following year, he implemented it again and this time asked students to volunteer for the program. He explained the mode of instruction to the students and parents. Only students who volunteered to learn with TLE signed up for his class. There were only 22 volunteers in 1998-1999. He also modified the recommended implementation guidelines according to his professional judgement concerning his own students, school and his own teaching style. Mainly, he kept a closer check on student performance and assigned more homework. However, TLE remained his main mode of instruction. For the school year 1999-2000, he had 57 students who volunteered to learn with TLE. Another teacher was also to be involved in using TLE. Unlike Crescent High School, Pearl's students did not bring home the CDs. His school's computer laboratory is networked and he used the networked version of TLE. Students completed their work in school. Every student had a computer to work with. He assigned homework and students did this homework with the help of the notes they took while going through the software in school.

#### Limitations of this Study.

Not many schools in greater Victoria and Saanich used the TLE program or implemented it on a large scale. Finding schools to participate in the study was a difficulty. One school bluntly refused to have anything to do with the study because the school discontinued using TLE after one term and the teacher who had implemented it is no longer on staff. In the school which

participated, only 25 out of 60 students stayed on the program during the year that TLE was implemented and many of the original 60 students had transferred to other schools during the time of this study. Of those students who were still with the school not many students volunteered for the interviews. Hence the population is very small and generalizations are difficult to make. The population for the distance education program was also very small. The school in Burnaby which successfully implemented the program was very willing to participate in the study, but approval from the school board could not be obtained in time for the interviews to be conducted with the students, before the school term ended on June 15 1999. The students would not be together as a class in the new academic year. Nevertheless, the interview with the teacher, Pearl, was most helpful. Originally, a student questionnaire was also planned, but because data could not be collected from the Burnaby school, the sample size was too small and quantitative analysis would become meaningless. Moreover, this study did not have a control group.

Ruby, one of the participants in the study was a former school teacher who successfully implemented TLE in his classes. He now works for the publisher of TLE. Although he discussed both the strengths and weaknesses of TLE, this does not change the fact that he is an employee of the company producing the software. Hence, his opinions could be biased and may not reflect the opinion of other teachers using TLE.

The data is self-reported by virtue of being interview data. Thus it could be inaccurate based on perception of the participants. For instance, teachers' views of student performance, their claim of the amount of time students spent on TLE and how TLE is implemented should be further verified by classroom observations and actual student grades.

## Chapter 4: The presentation of data

### Crescent High School

The first set of data consists of interviews with eight students and a teacher in a public school in Greater Victoria. The school will be known as Crescent High School in this study. The short interview with the teacher, known here as Jacinth, was conducted through the telephone. It took about fifteen minutes. The other interviews were all face to face interviews conducted in the school. The school had implemented TLE in the 1997-1998 school year. TLE was used as the main mode of instruction and the program was implemented as recommended in the four-day teacher training sessions.

The first student participant, Jasper, is an average student who never found Math to be her strong subject. Her grades went from B in grade 8 to C+ in grade 9. She found learning with TLE to be fun and different from the usual textbook and classroom teaching. The ability to study independently was important. She felt that the practice exercises were really helpful and sufficient. However, she still preferred the teacher to explain the lesson in a traditional classroom setting. She thought that TLE was ideal as practice software rather than software used as the main mode of instruction. She preferred to see the teacher teach the lesson step by step. Moreover, she felt that teachers were able to ask appropriate questions during lessons. Such questions help her understand the concepts. This is missing in the software. She also could not

draw diagrams on the screen. Such a feature would be useful. If the software could present a teacher talking and explaining the concepts step by step, she felt that she would also prefer that.

I like teachers to teach and ask questions, it helps my understanding.

She also brought up the fact that many of her classmates were behind time towards the end of the year. Since they were allowed to take the quiz only after a minimum of fifteen practice examples, many students skipped practice questions. Since nobody checked on them, they got away with it. She felt that if there were a teacher in a traditional classroom, this would not have happened. She felt a strong need for the software to keep track of student progress and work done.

...If I can stick a disk in and check which questions have been done, that would be good.

As for the Internet, she used it for projects and email. If TLE were linked to the web with relevant content to help in her project work and lessons, that would be good. She believed that grade 8, 9 and 10 students can learn with a software such as TLE but grades 11 and 12 would require a teacher in a traditional classroom setting so that concepts are explained clearly.

The second student participant, Chalcedony, was also an average student. She claimed that she learned by concrete examples and manipulating physical objects such as manipulatives. She found it difficult to learn with TLE and opted out of the program. She found the questions too difficult. She always

answered the questions wrongly and this prevented her from moving on with the program. It frustrated her.

I need to touch things to learn, it does not work for me by just clicking on the buttons. When the questions were too hard, I always get the answers wrong all the time and I do not know how to do it..... I so much like to have a teacher, or else, if you do not know how to do it....

She did not like the software and requested more worked examples, more help when needed and more steps. She preferred a real person talking and she missed using manipulatives. During the interview, she mentioned several times that she liked to learn by manipulating real objects and not by simply clicking objects on the screen. She could not learn with TLE.

I like a real person to ask me questions. I actually like to touch it and feel it.

The third student participant, Sardonyx, was an above average student. He had been an "A" student for Math throughout his school career. He liked TLE and had absolutely nothing bad to say about it. He had no problems filling in the blanks and understanding the concepts. He could do all the examples and thought that the exercises and extra questions were useful and at the right level of difficulty. He liked learning with TLE. He could progress at his own pace and there was no group work. He preferred self-study and did not like group work. He suggested that the software include more proofs and simulations. He

preferred abstract ideas and seldom made use of manipulatives. He did not think that was necessary. He was disappointed that TLE is not used in grade 10. He enjoyed the freedom of learning with TLE.

The fourth student participant, Carnelian, was an average student who did not like Math. When asked if he liked math better after using the software, his answer was a sure 'no'. He still hated math. However he admitted that he liked math better when learning with the computer. His grades went from B in grade 8 to C+ in grade 9. Like Jasper, he felt that there were no checks on students. They had to record their grades on a mark sheet, but there were no checks. He found notes taken from the software to be helpful during review. He appreciated the freedom in being left alone to study and claimed that he learned less from the traditional classroom setting. He had more time to go through the lessons when using software.

It's freedom. I like being left alone. I don't really learn stuff by the teacher teaching the whole group. With the computer, you have more time. I have more time to do it.....if I don't understand, I can ask the teacher.

He said that his friends were not on the program because they learned better with textbooks and hence they opted out, but as for himself, he found textbooks not as helpful as the computer software. Consequently, he was not able to discuss the lessons with his friends. His classmates using TLE were covering a different topic from himself and hence again, he could not discuss anything with them. Nevertheless, he said he did not miss group work. He found that

textbooks did not give enough examples. He found the problem solving examples and exercises to be most helpful in the software. He felt that he learned better with the computer.

Problem solving questions were good. I would figure it out. I do better (problem solving) with the computer.

He found the pacing of the software slow and wished it were faster. He would also like to see more reward for answering questions correctly.

The fifth student participant, Chrysolite, was an average student who scored a B in grade 8 and a C+ in grade 9. He liked sports and wanted to pursue a career in it. He liked TLE because it was fast and easy. He went through the program at his own time.

“You can do it in one or two days and if you don’t understand, you can take a longer time....I do most of the work at home.”

He was very proud and glad that he finished the exercises ahead of most other students. He seemed pleased with his ability to discipline himself. When asked if he could be trusted to do his own work, he answered a confident ‘yes’. He thought that TLE was suitable for grades 11 and 12 because older students are more self-disciplined. He liked the problem solving questions in TLE because the questions made him think. He felt that the CDs contained more information than the textbook. He would like to see more hints and help when he is unable to get the correct answer. However, he said that he ultimately still preferred the teacher to teach as that arrangement is more structured. He preferred the teacher to teach step by step. He did not think that the software changed his

dislike for math. If he were given a choice in grade 10 to use TLE again, he would not choose to go through such a program. The reason was because he liked to write things out on paper. He learned by drawing pictures and diagrams on paper using a pen or pencil. He had to look at his own diagram.

Probably not, I like to write things out.....I draw pictures...not able to draw pictures on the CD-ROM. I usually work with paper, pen and the computer.

He was also a person who liked to discuss his work with his classmates. Since his friends were at a different section of the software than himself, he was not able to discuss his work. Hence, he preferred the usual classroom setting.

Usually I ask my friends before asking the teacher. With the CD-ROM its kind of different. Everyone is doing different parts of the program at different times and I am not able to discuss the lesson.

He felt frustrated when the labs were closed and he could not work at the program. Although he could work at home, he would have preferred that the computer labs were more accessible. He used the labs when available.

When the labs are open, I will demand that I can use it.

When asked what new features he wants to see in the program, he said:

Draw your own picture in the computer. Print the information.

The sixth student participant, Beryl, is an average student in mathematics. He usually scored a B+ for his exams. However, when using TLE, his grade slipped to a C and he requested to leave the program. He noted that half of the students did not stay on the program. He was a young musician who

did not like math. While he was not terrible at it, math was not his best subject. He preferred English. TLE did not increase his interest in math. He did not think that he was learning as well with the program. He liked to learn using paper and writing the solution instead of just keying in the answer. He preferred the teacher to explain the concepts and use diagrams instead of reading it off the screen. Moreover, he liked to write out his thoughts, but the software laid out the solution for him step by step and this might not be the solution procedure he had in his mind.

I like to work out the answer on paper, not just key in the answer. I write what I think, but in the computer, it comes step by step for you.

When asked if he would recommend TLE to a friend, he said it all depended on how his friend wanted to learn his math. He felt that it is best suited for people who like to do math in their heads and not those who have to write the solution out on paper. Like Chalcedony, he liked to draw diagrams and move physical objects around in learning math. Although not heavily dependent on manipulatives, he felt that clicking and dragging objects on the screen was not helpful enough.

On a philosophical note, he believed that computers would one day take over for the teacher because it has taken over everything. However, he was really happy to note that when that happens, he would not be in school anymore. When told that his children would be in school, he said:

My children will be brought up with it, so they won't mind, it is ok.

However I have been taught by a teacher for ten years and will find it difficult to learn with the computer without a teacher. If you are brought up with it, it is ok.

He, however, said that he liked the problem solving and the diagrams in the program. The speed was just nice, although it was sometimes a little slow. He was not the type who liked group work. He preferred to learn independently. The main reason for his opting out was because he wanted to write and draw his own solution on paper. When asked what features would improve the program, he said that there should be freedom to draw and move objects about the screen. Ability to type in sentences while solving a problem would also be useful. Homework should be saved on disks so that they could be brought home and students could continue to work from home. The first version of TLE did not have this feature and when students used a different computer, their previous work was not registered. They had to do the questions again. He found the exercises in the CDs to be insufficient and would like to see more.

Homework... save it on disk. If you do your homework in school and bring it home to continue, it is not done on the home computer. So you have to do it again, slows you down. The homework is not enough, would like to see more.

He also commented on the self-discipline required to go through such a program. He noted that in a classroom, the teacher makes the students sit down and do their work. The atmosphere in the classroom therefore makes it

easier to do work. However, in the computer lab, students left on their own without teacher orchestrated lessons could come and go as they pleased. They could bring home the CD.

If you are using the computer to learn math, people come and go as they please. In the classroom, the teacher makes you sit down and do the work. The classroom atmosphere makes it easier.

Topaz was the seventh student participant. He was an above average student for math. His grade was usually an "A". He liked math and spent most of his free time on computer games. He preferred to learn with the computer. It was faster and easier; he understood more. He would recommend it to his friends and could not understand why so many of his classmates opted out of the program. He found the questions easy and had no problems going through the program. He liked the step by step approach to problem solving and thought that the feedback was sufficient. He saw no need in drawing his own diagrams. He felt that his interest in math had not changed by the use of TLE. For this participant, he and one of his friends made it a point to work together; hence there was discussion and exchange of ideas.

Me and my friend worked together at the same pace, we discuss our work.

However, he did not miss group work. While he found manipulatives useful, he could do without them. He had nothing negative to say about the program except that he found it to be a bit slow at times and the navigation was not very

clear. When asked if he preferred classroom teaching or learning with the CDs, he said that both were important. Teachers are important because they ask the right questions. He felt that this kind of arrangement was suitable for grades 7,8 and 9 because for grades 10, 11 and 12, the content becomes more challenging and abstract and a teacher is required to explain the concepts. Although he agreed that simulation programs were helpful, he insisted that the teacher is important.

The teacher, Jacinth, started with 60 students and only had 25 left on the program at the end of the year. She taught the students for both grades 8 and 9. Some students went back to using the textbook; others used only TLE and there were those amongst the 25 who used both the textbook and TLE. Her students were of mixed ability, some very bright while others were slower. Students liked the idea of learning with computers and parents were also very supportive and encouraging. They wanted their children to try something new. She said that if she were to use TLE again, she would not implement it this way. Instead, she would use it as a supplement to the main classroom lesson and textbook. As for academic results, all the grade 9 students sat for the same examination. Weaker students on TLE did better on the exams than if they were not on the program. This was because they could go through the lessons again and again using the CDs. All her students sat for the same examination at the end of the year. They were not allowed to redo the exams if they did not do well. Her problem was that there were not enough computers for all of the students at the school and some students had no computer at home.

### Distance Education Users

The second set of data was consists of interview data collected from two distance education teachers and a student and a parent who used TLE. Sapphire was a veteran teacher who had been teaching for thirty years. At the time of the study he was with a distance education centre. He and 15 of his students used TLE in 1997 to 1998 in a pilot project. Only two of his students stayed on the program till completion. They were above average students with strong parental support. He explained that in a normal school, there would be a teacher-mediated environment even when using a program like TLE. Students could still ask the teacher questions when they went to school. However, for distance education students, the teacher is not close by and they are left on their own. They are more reluctant to pick up the phone or send an email when they encounter difficulties. Left alone at home, they are less motivated to complete the exercises. Hence, only two students completed the program successfully. These two students were able to understand the content. Even so, one of them told the teacher that although he scored an 'A' grade, he was still not sure if he fully grasped the concepts. It seemed that there was "no closure" as the teacher puts it. The student did not see the whole picture and was not sure if what he understood was what the program was trying to teach. Sapphire monitored student progress by keeping a copy of the exercise templates and notes. Each time students completed an exercise, they recorded a tick with the grades on these mark sheets. He gave six tests for eight to ten lessons. He

found it necessary to conduct review lessons before a test. This, he said, would refresh the students' memory, clarify concepts and give a form of lesson closure.

Although he felt the program was really good, he cautioned about implementing it on a large scale. The Ministry of Education of B.C. was preparing to buy a province wide license for TLC. Schools wanting to use it could purchase it at a special price. He felt that there was too little evidence to make generalizations about the effectiveness of the program. First, he noted that computer programs have great difficulty in allowing for special symbols like square root, exponents, algebraic equations etc. In fact students cannot type in these symbols. Second, students could not draw diagrams in the program. Model building was not possible. Third, programs tend to accept one unique answer down to the last decimal point when in fact, some questions do not have unique answers. Students had to write a paper and pencil, and he is worried that looking at a screen is different from looking at a piece of paper in a textbook. He claimed that learning via a computer is 25% less efficient than using a regular textbook, although he agreed that this is a matter of getting used to the medium. In a normal school, an option of going back to the usual mode of classroom instruction should be given to students who do not want to continue with the program. They could use TLE for enrichment or remediation.

Sapphire commented that mathematics teachers liked the program but *not all students like it. Sapphire found the blanks on almost every screen too pushy.* This might not work for slower students.

Work, work, work and more work. It goes on and on. It locks students into a working mode. Can be very tiring on the students especially the slower ones.

Students think of the teacher's opinion of their ability as important. They want a teacher who is a worthy judge of their ability and progress. For students who preferred to learn with the CDs instead of the usual teacher talk in class, there was a trade off. On the one hand, they did things in their own time without the teacher nagging at them. On the other hand, computers do have limitations. The teacher knows the student. If the student were having a bad day, a teacher could modify the lessons to suit the mood. Teachers are flexible; they can try different approaches and say encouraging words. Teachers can ask questions to probe for understanding and clarify doubts. Students can also ask other students questions to probe their understanding and challenge one another's intellect. He felt that there should be three levels of difficulty, what he called paths in a program: the below average, average and above average. Students could choose their own path.

He thought that the teacher talk in the CD was good. Demonstration of how things are done, like cancellation and manipulation of an equation is helpful. Companies must sell their product as a superior way of teaching and if a program is sensitive to the needs of students, it would be ideal. A program that gauged the ability of the students and branched accordingly to the relevant level of difficulty would be useful. For example, if too many mistakes were made, the program would change path and becomes easier and vice-versa.

Solving questions in many different ways does not sit naturally with students. Usually after getting the correct answer, students will automatically go to the next question. It is only in teacher mediated settings that students are encouraged to solve problems in many different ways. In the case of distance education, teacher mediation is not there. He thought that TLC had too few pop-ups or hints telling the students what to do when an answer was not correct. Weaker students may want to see the answer and solution as a whole immediately rather than having it break into parts. A textbook and workbook to come with the CD would be ideal.

Jade and his father, Diamond, were interviewed in their home. Jade was a student with outstanding capabilities. He was attending grade 7 at the time of the interview but had completed TLE grade 10 with the distance education school. He found the questions in TLE challenging but had little problem going through the CDs because if he needed help, his father or his teacher in the distance education school was able to help and encourage him. He did not ask his school teacher for help because his classmates were in grade 6. However, he said that there were too many steps and he could do the problem in fewer steps. He knows of other methods to solve the problem. When asked if he preferred the textbook or a CD, he said he liked the CD because there were more pictures and simulations.

There are more things in the CD. It is a quicker learning process.

Since he was ahead of his class by two grades, he was under no pressure to complete the grade 9 and 10 courses. He worked at his own pace and enjoyed the freedom. He spent about an hour a day working at the CD. He monitored his own work and went on to the next section only after finishing the previous step. He mentioned that it was easy to cheat with this course. If students used the CDs in school, they might not complete all the self-checks and exercise problems. Pressed for time towards the end, they might key in all the wrong answers, copy the correct answers as the program revealed them and do the entries again entering the right answers. If all they had to do was to keep a mark sheet, cheating was easy. Students who did all the exercises would be unhappy because their friends cheated and got away with it. He thought that if the program were used in school, stricter control would be needed over the monitoring of homework. He sat for three exams on three major parts of the program.

As for problem solving, he felt that he was better able to solve problems after the course. However, he hoped that he could draw diagrams on the screen. He used pencil and paper along with the CD. He had always liked math and did not think that using the CD made him like math better. He felt that the questions were realistic except that in some instances, they tried to use 'nice numbers' to get a nice answer. He did not believe in rote practice and did not learn by that method. He felt that the questions in the CDs were sufficient. He would welcome a web link.

Jade liked manipulatives because they helped him understand better. However, he thought that if he understood the concepts, manipulatives could be a waste of time. He liked it only if he could not understand the concepts. He felt that he did not mind not using manipulatives while using the CD. He also said that the geometry section was great because it simulated the movement of manipulatives. That was good enough for him; he did not think there was a need to manipulate objects himself to understand the work. He liked proofs and hoped that the CDs would show more proofs. Although his dad would like him to interact with other users, Jade thought he could learn by himself. He liked to study by himself and disliked group work because he had to teach the slower students all the time. He found that TLE grade 10 was a lot easier than TLE grade 9. Moreover, TLE grade 10 came with a textbook.

Jade's father, Diamond, was also interviewed because he coached Jade at home. He thought that the program was inappropriate for students who are below average. The program is really heavy going. Students without an interest in math would not have the determination and patience to sit through the program. The program prompts the user at every screen and slower students who were not able to understand the content would get every blank wrong. He thought that this would discourage the users. They would not do all the questions. Computers are supposed to motivate students but if the course is too difficult, Diamond felt that it would do harm. Different students learn differently. Some students require drilling. He felt that there were not enough practice questions for that purpose. The method of lesson presentation in the CDs

requires good reasoning skills on the part of students and students weak in Math may lose interest. They may not get to the next step without assistance. Diamond felt that TLE is a good tool for learning concepts, but to implement it on a large scale in the classroom and use it as a main mode of instruction could spell disaster, simply because different students learn differently. Moreover, checks on students' homework are necessary. It is a great program for very bright and self-motivated students.

Emerald was the other distance education teacher interviewed. He participated in the pilot program to use TLE in distance education in 1998-1999. Eight students were selected from amongst the grade eight students for this project. These students were selected by Emerald. He selected those students who demonstrated that they were capable of independent study and were responsible for their own learning. Of the eight students, only four students completed TLE successfully. These were the above average students. Emerald liked the software. There were no technical glitches and the software was user friendly. Students had no complaints about not knowing how to use the software. Student reports and files were emailed to the teacher. He liked the new feature of TLE where students' grades and progress are tracked and recorded. He thought the program was well produced because the Explorer section goes into the topics in depth. Simulations of algebra tiles and the spinner in the probability module helped students understand concepts.

In his program, students had to sit for six tests, each worth 15%. All the tests would hence form 90% of the total mark. The remaining 10% came from

grades obtained from student notes. Students were permitted to sit for the test only if they did all the exercises and self checks. If their grades for the self-check section were not good, they were not allowed to take the tests. He believed that in a distance education setting where the teacher is separated from the students, there is a lack of encouragement to continue. Unlike in a computer lab where there is a teacher and other students, distance education students are left on their own. TLE is suitable for the self-motivated and better students or what he called students with outstanding capabilities. If implemented in a usual school, there should be an option to allow students to return to the usual classroom setting because not every student can cope with learning with TLE.

### Successful Implementers of TLE

The third set of data was collected from a public school teacher in Burnaby and a former teacher from Vancouver. The teacher from Burnaby, Pearl, has been using TLE since 1997 and had been successful with it. His school was involved in the 1997 psychometric study commissioned by the company who publishes TLE (Fitzsimmons & MacNab, 1997). The school was to have two classes of grade 9 students using TLE in 1999-2000 instead of one class as in the 1998-1999 school year.

Pearl explained that in 1997-1998 the school made two classes of students participate in TLE program. He emphasized that his school administration was very supportive of his effort to use TLE. There were about

62 students in the two classes. Since there were two classes, two teachers were trained to teach with TLE. Each Math session lasted one hour and fifteen minutes held in the computer lab on alternate days. Every student had a computer to work with. The teacher acted as facilitator. There were no traditional classroom lessons. Many students did not sign up for the program willingly and complained about it. Some simply said they could not learn with the software as they were not accustomed to reading off the screen. Five out of each block of students opted to join the class where normal lessons were conducted. Some parents were also not happy with the program.

That year, Pearl implemented the program just as it was recommended by the training sessions. He did what Jacinth did. He did not keep a very close check on student notes and did not do much marking because that was not emphasized during the training. In fact, they were told during the training sessions that it would be too much work to mark all the students' notes. Since that was the first version of TLE, the program did not have a progress-tracking device to track student progress. Hence, just as in the case of Jacinth in Crescent High School, students' progress was not closely monitored. Unlike Crescent High School, Pearl did not let his students take the CDs home. Students worked in the laboratory with networked computers. In 1997-1998, there were network problems. Pearl acted partially as the network administrator and trouble-shooter.

In the school year 1998-1999 , Pearl asked for volunteers to sign up for his lessons using TLE. He explained to the grade 8 students what TLE was all

about and how it was different from the usual classroom lesson. Students who were interested in using TLE had to ask their parents for permission to sign up for his class. Twenty-two students signed up. Pearl fell sick and was on sick leave for the first half of the year; consequently, the program was not implemented until the second half of the school year. One student opted to go back to the traditional mode of instruction while Pearl was on sick leave. When he returned, the students were really relieved to see him and were very eager to start learning with TLE. One student's grades improved from 20+% to 70+%. This student could not do well in the usual classroom environment and his attitude improved with the use of TLE. However, Pearl cautioned against using grades as a yardstick to measure success because some students' grades fell when they used the program. He said that amongst those who signed up, there was a range of learning ability, some slow learners, as well as some very bright students. He did not notice any huge improvement of grades amongst the majority of the 21 students. Students were however motivated to learn with TLE and parental support was also good.

Administrative support was important as the administration prepared the time table and administered the booking of lab hours to suit the needs of Pearl's lessons. There were also fewer network problems that year. The new version of TLE allowed the teacher to track students' progress and kept a record on the network. Vital information such as time of logging on, sections and screens the student visited, exercises completed, number of tries before the correct answer was obtained and grades obtained were all recorded on the network. Moreover,

there was a student workbook. Pearl did a lot more marking this time. He set homework from the student workbook. Students had to do these homework exercises and hand them in. They also had to take down notes as they went through the lessons. Pearl collected these notes and marked them. From these notes, he was able to tell if the student understood the lessons and which areas of the topic the student had difficulty in. If the misunderstanding were serious, he would tutor the student individually on that particular concept. If the misunderstanding were common for many students, he would conduct lessons for that group to clarify the concepts. He held group discussions and assigned group work as well. If the whole class were confused with a concept, he would explain that concept in a lesson as in a traditional classroom setting.

For that year, he marked 70 assignments for grade 9. He admitted that it was difficult at times because a lot of effort had to be put in. He felt that students must be held accountable for their work and close checks are necessary. Although reading and marking the notes involved a lot of hard work, he felt that it was really helpful and necessary. Being an on task person himself, he took the trouble to ensure that students did their work. He noted that students learned how to learn independently. They learned how to read and pick out important points or concepts and write out these concepts. This, he said is a valuable ability. Moreover, he noticed that students learning with the computer were more willing to help each other with problems.

As for the management of students in the lab, he noticed that some students who could not behave themselves in the classroom were very well

behaved in the lab. The group of 21 students he had was great and gave no serious problems. Some were really creative and tried to surf the web during class time despite the fact that Internet access was denied by the network administrator. He felt that the physical layout of the lab affects the management of students in the lab. To address that matter, he renovated the labs for the school year 1999-2000. The new layout works in such a way that the teacher's table is at the back of the class and from there, he can see all the students' screens. The new layout also enables the teacher to move freely around the lab so as to attend to students in need of help. All his students liked the lessons and word spread to the grade 8 students that TLE was a great program.

For the year 1999-2000, he had fifty-seven volunteers. There were two classes planned with two teachers using TLE. Pearl thought that willingness on the part of the students and parents to participate in the program is important to the success of its implementation. He enjoyed teaching with TLE and strongly believed that it was a good program. He seemed pleased with the effort he put in to make the program a success. The effort was worthwhile.

Ruby worked for Nelson Canada and the BC Ministry of Education. Ruby was the representative for The Learning Equation in the province of BC and was one of the content editors for the program. He was formerly a teacher in North Vancouver and had used TLE. He explained that initially, the plan was to implement TLE in a large scale making it the main mode of instruction. However, now it is up to the teachers to adapt and use the software. They can use it as the main mode of instruction, use components of the program, use it

for student self-evaluation, use it as enrichment, use it as a supplement or any other ways they can visualize. Teachers are still learning and adapting the software to their lessons. They are beginning to realize the importance of group work and monitoring of student progress. TLE works better in certain areas. He explained that teachers who want to implement TLE have to attend a four-day workshop conducted by Nelson Canada. They are briefed on strategies to implement the program. There are also sharing sessions by teachers who have used TLE. However, he said that professional development is expensive. In attempts to improve the software, Nelson had added a lot of new features such as a web link and progress tracking capability. The company had initially developed the software under a guaranteed use of the resource by schools in the Western Provinces. The company invested \$7 million in the development of the software for grades 7 to 10. They hope to market the product overseas and to recover the development cost in time to come. When asked why grade 9 TLE is more heavy going than grade 10 TLE, he said that grades 7,8 and 10 are more consistent. They are not as demanding as TLE grade 9 so that students can spend more time on the lessons.

## Chapter 5: Data Analysis and Findings.

Data was analysed by looking for trends which emerged from the comments made by the participants. These themes were refined and then organised into ten sections. These are: The importance of the teacher, the implementation of the program, the design of the software, students with outstanding capabilities, student morale and attitude, other skills acquired by students, administrative support and teacher commitment, student achievement and finally geographical locations.

### The Importance of the Teacher.

Looking at the data, all students interviewed preferred the teacher to explain the concepts in class. Students made statements such as the following:

...I so much like to have a teacher.. - Chalcedony.

I like teachers to teach and ask questions, it helps my understanding. -  
Jasper

I prefer the teacher to teach step by step - Chrysolite

I have been taught by a teacher for ten years... - Beryl

Chalcedony found it difficult to fill in the blanks in every screen and hence could not progress with the software smoothly. This seems to suggest that slower students are more dependent on the teacher. In the data, Jade, Diamond, Sapphire and Emerald also felt that average and below average students would benefit more from classroom teaching. The fact is teachers can orchestrate a discourse to probe student understanding and misunderstanding. TLE software,

cannot read the students' minds and diagnose the misunderstandings. Consequently, each time an incorrect response is entered, the same feedback, explanations or hints are given regardless of the type of mistakes. Sapphire, the veteran teacher, said that students who preferred to learn with the software have to settle for a trade off. While they get to work at their own pace without a teacher nagging at them, they also miss out on the teacher's opinion of their work.

Students want a teacher who is a worthy judge of their ability and progress. For students who prefer to learn with the CD, there is a trade off.

- Sapphire.

Teachers can say the right words of encouragement and can alter their lessons to suit the individual student's ability, temperament and mood. The conclusion would be that while most students liked learning with the computer software, they still want access to a teacher's guidance and help.

#### The Importance of the Teacher and the Implementation of the Program.

Related to the role of the teacher is the implementation of the program. The mistake made in 1997 was that teachers listened to the recommendations of the company producing the software as to how they, the company, wanted it to be implemented. Teachers attended a four-day workshop on how to use and implement TLE and then they were all prepared to 'download' this program on their students. Cuban (1986), in his study of attempts to use technology in reforming schools, noted that these efforts often mistakenly attempted to impose

the technologist's or policy maker's vision of the appropriate use of technology in schools. This mistake was evident in the implementation of TLE in 1997. Different schools in different provinces and different districts face different situations unique to their surrounding. It is naïve to assume that a program requiring a major shift in teaching and learning modes can be implemented uniformly in all schools. If such a quick fix were available, implementing technological changes in schools around the world would not be a subject requiring such intense study. What works for one region might not work for another. Teachers in their own classrooms are the best judge as to how a program should be implemented. They have to adapt the software to their own situation. They have to take into account their own personality, style of teaching, students' background, ability and preferences. This is in addition to administrative support and hardware considerations. Ruby mentioned that initially the plan was to implement TLE on a large scale. TLE was intended to be the main mode of instruction in place of the usual classroom lessons. However, today, the publisher and teachers who have successfully implemented TLE recommend that teachers adapt TLE to suit their own classroom situation. They can use it for distance education, enrichment, remediation, drill and practice, homework, simulation or as a reinforcement of what is being taught in class. Teachers such as Pearl and Ruby who are comfortable with making TLE the main mode of instruction can continue to do so. However, contrary to Cuban's (1986) conclusion that most software is unreliable and teachers do not receive enough

assistance, TLE is user friendly and there had been no complaints that users did not know how to use TLE. There were also no complaints of programming faults.

Glennan and Melmed (1996) emphasized the importance of implementation of CAI. Tapscott (1996) noted that teaching in this digital age requires teachers to give up the traditional lecture style mode of instructions. They become more like facilitators. They have to create a structure to facilitate group discussion and individual coaching. Teachers are also no longer in full control of the lesson. Teachers make suggestions and ask questions to encourage students to think. Pearl was able to do all that. He put in extra effort to check on students' work and conducted individual tutoring and group tutoring and discussion. He also assigned extra homework and read all the students' notes. In March of 1998, ITP Nelson published an article written by Eddie Mah, a teacher in Edmonton who successfully implemented TLE. He recommended that teachers plan and conduct individual and group work for students away from the workstations. In the framework outlined in the Curriculum and Evaluation Standards for School Mathematics (NCTM, 1989), the NCTM states that it expects students to solve problems collaboratively. Students must talk about the Mathematics they learn and listen to others' views and ideas. TLE, being a stand alone CD-ROM software does not facilitate group work because students working at their own pace may not be covering the same topics as their friends. Discussing the lessons with their friends becomes difficult. Some teachers using TLE have students work in pairs but in Pearl's classes, students worked on individual workstations. Some teachers 'force' every student to work at the same

pace so as to facilitate discussion. Beatt (1997) conducted a qualitative study on TLE on behalf of ITP Nelson. He observed sixteen classes in four provinces and discovered that the most effective classes were those where teachers allowed students to work at their own pace. Beatt observed that these classes were more effective because students spent longer hours with math, they progressed at their own pace and took responsibility for their own learning. In these classes, teachers were willing to let go of their traditional role as the “sage on the stage”. This would mean a lot more work for the teacher when it comes to planning group discussions. This was what Pearl discovered. He had to keep track of individual students’ progress in order to be able to bring together a group with a common problem.

Mah (1998) emphasized student note taking and posting good samples for other students to read. Teachers must also plan and establish clear classroom routines and procedures to encourage students to get on task. This is classroom management. It can be seen from the data collected that Pearl managed his class very well. In fact, he even renovated the computer labs and re-arranged the seating arrangement so that he could see the monitor screens of all his students. In the new layout, the instructor can move easily from one workstation to another without obstruction. Other suggestions by Mah include a parent orientation, planning for a resource bank in case the computers are down, and ensuring that students have computers to work with.

Mah mentioned that the implementation of TLE also affects the students. They have to adapt to major changes. They are now in control of their own learning, can work at their own pace, must adapt to the teacher as a facilitator, and must learn how to interact with the software to maximize learning. For some students, all of this can be really demanding.

I have been taught by a teacher for ten years and will find it difficult to learn with the computer without a teacher. If you are brought up with it, it is ok. - Beryl

Usually I ask my friends before asking the teacher. With the CD-ROM it's kind of different. Everyone is doing different parts of the program at different times and I am not able to discuss the lesson. - Chrysolite.

The implementation of CAI has to take into account the adjustment students have to face. It is the responsibility of the teacher to provide individual tutoring and to organize group discussions away from the workstation. Means and Olson (1995) reported that the early stages of technology implementation make the teacher's job harder. They have to give individual attention to students, monitor progress and more time is needed to plan and prepare lessons. Technical challenge is only one part of the problem. It is naïve to think that the computer can lighten the teacher's workload.

## The Importance of the Design of the Software.

TLE, with its step by step approach to problem solving, is a linear multi-media program. Students are put in control of their own learning and they can work at their own pace. This is one of the features which all student participants and teachers like.

You can do it in one or two days and if you don't understand, you can take a longer time. - Chrysolite.

Its freedom, I like being left alone. - Carnelian.

Computer guided learning such as TLE allows for individualized instruction. In their book Instructional Technology for Teaching and Learning, Newby, Stepich, Lehman and Russel (1996) defined Individualized instruction as instruction in which the content, pacing, instructional sequence, media and approaches are determined by the individual student's learning needs, abilities and attitudes. It would be a waste if teachers 'forced' every student to work at the same pace for the sake of easier classroom management and monitoring of progress. As it is clear, the implementation of CAI will not lighten the teacher's workload.

TLE has interactive simulations like the use of algebra tiles and the spinner in the probability module. All participants liked the simulations and would like to see more of them. The above average students in particular asked for more proofs in the form of simulations. Simulations help students understand concepts in a visual way. Students interact with the software and see the effects

of their actions. Feedback is given in pop-ups. They appear instantaneously whenever the user keys in an incorrect answer. These short hints or feedback are written in plain English and are direct and to the point. Sapphire thought that there should be more feedback or hints to solve the problems. Most participants felt that the feedback given when an answer was incorrect was useful but concrete learners like Chalcedony refused to learn with the software. She wanted more worked examples, hints and help. Chrysolite also hoped for more hints and feedback when he could not get the correct answer.

The program's attempt to teach via problem solving and solve the same problem in many different ways is consistent with recommendations of the NCTM. All participants liked the problem solving questions. They believed the questions helped to improve their problem solving abilities.

Problem solving questions were good. I would figure it out. I do better with the computer. - Carnelian.

Although Beryl opted out of the program, he agreed that the problem solving questions were helpful. However, he mentioned that although the program tried to solve the problem in many ways, the program laid out the method for the students and this was not always the procedure he had in his mind. Jasper mentioned this also when she spoke about why some of her friends hated the program. Jade said that he knew how to solve some of the problems in other ways not taught in the program.

TLE also has drill and practice features as there are 25 practice questions per lesson and 56 lessons in the grade 9 CD-ROMs for that purpose. This

excludes the ten questions in the extra practice section in each lesson. Moreover, TLE has an accompanying student workbook and teacher's resource guide. It is also linked to the web. The monitoring of student grades is strict in the new version of TLE. All except Beryl and Diamond felt that there were enough questions in the software. Diamond felt that the practice problems might not be enough for some students who might require more practice.

Although students are free to go through the lessons at their own pace, TLE can also be very restrictive. There is a blank in almost every screen. While these blanks ensure that students are actively involved in the thinking process and constructing their own understanding of the concepts taught, it also posed serious problems to some students. Chalcedony requested more steps and hints in solving the problems. She became frustrated when she could not move on each time she keyed in a wrong answer.

When the questions are too hard, I always get the answers wrong all the time and I do not know how to do it...." - Chalcedony.

Sapphire felt that the software was too heavy going and pushy. It locks the student into a linear path and the student has to go on.

Work, work, work and more work. It goes on and on. It locks students into a working mode. Can be tiring on the students especially the slower ones. - Sapphire.

The frustration experienced by Chalcedony was accurately predicted by Diamond. He saw that students who could not fill in the blanks correctly cannot proceed and will become discouraged. They will hate mathematics even more.

Jade said that while the goal of using the computer is to motivate slower students, a program that is too difficult could do the opposite.

Clariana (1997) found that the navigational set up of some programs encourages students to repeatedly key in the wrong answer just to obtain the right answer so that they can key that in and proceed to the next step. This was exactly what happened in the first version of TLE. Jasper and Beryl confirmed that their friends cheated in this way. A check with the others confirmed this to be true. Jade also pointed out the problem.

....Many people skipped practice questions....if I can stick a disk in and check what questions have been done, that would be good. -

Jasper.

Homework...save it on disk." - Beryl.

We had to record our grades on a mark sheet, but there were no checks." - Carnelian.

This shows that young people are very creative. It is also evident that students want teachers to recognize their effort; they want monitoring of homework. The new version of the software tracks student's attempts at getting the right answer, the number of times a particular section was visited, and when the user visited it. Clariana (1993) studied the achievement effects of advisement in the form of progress reports. He found that students receiving reports that provide information concerning time spent on each activity, activities completed, the percentage correct for each activity, time spent on each activity and the date which the activity was completed demonstrated significantly higher mathematics

achievement than students who did not receive such reports. The new version of TLE released in 1998 has features to track student progress.

While there are disadvantages to the step by step set up, Clariana (1997) also mentioned the advantages. Slower, passive students are encouraged to become active and try to fill in the blanks. Showing the correct answer or giving appropriate hints help them in understanding. In the present study, this argument is supported by Jasmine who said that the weaker students tended to improve with the use of the software because they could use it again and again. Students who were reluctant to reveal their ignorance for fear of ridicule or rebuff will find the computer non-threatening. An incorrect answer will not lead to a personal comment by the teacher in front of the class. None of the student participants found the computer to be threatening. Teacher Pearl also mentioned the dramatic improvement in grades of one of the weaker students. No other students reported any dramatic improvement in grades. The step by step approach could have been adopted because it is perceived that mathematics has to be learned this linear way.

It can be seen that the design of TLE, with its problem solving approach to teaching using multi-media, simulations and a thorough set of drills is in line with instructional design principles which recommend that software should incorporate the various learning theories. Wild and Quinn (1998) and Schwier and Misanchuk (1996) suggested this to accommodate different student needs. Newby, Stepich, Lehman and Russell (1996) wrote that truly individualized attention is rarely achieved in the traditional classroom. It is difficult for a single teacher to

accurately determine the experience and ability of all students and it is economically not possible to provide every student with a personal tutor. Educational software can cater to different student needs by providing options for tutorial, drill and practice, simulation and multi-media presentations to meet diverse student needs.

The design of the software appears to meet the needs of average and above average students. All the students participants who stayed on the program were either average or above average students. In fact, the above average grade "A" students had no negative comments about TLE. Through experience, Emerald and Sapphire observed that students in the distance education agency who successfully completed the program were the above average students. Average students still very much prefer the usual classroom lessons although they were able to learn with TLE. There is evidence that the software is too demanding for weaker students. It could be harmful if these individuals were made to use the software without individual coaching and group discussions. The Software Publishers' Association cited the work of Dalton (1990) found that students generally do better with user controlled software rather than program paced software. However, he added that for low ability students and students with little prior content knowledge, user controlled software should be used with caution. This leads again to the conclusion that the role of the teacher is important and the program has to be implemented properly. There have to be stringent checks on student progress, and individual coaching and group discussions have to be planned.

### The Different Cognitive Styles and the Design of the Software.

TLE is a linear program. Students need to key in the correct answer before going on to the next step. Hoffman and Waters (1982) cited by Ross and Schultz (1999) in their article "Can computer aided instruction accommodate all learners equally?" said that linear software is suitable for CS and AS learners who like to learn in an orderly sequence. It would be painful for AR and CR learners because they like to learn by building relationships with people and they learn in a non-sequential way. They prefer to explore freely the various parts of the program as and when they choose to. AR and CR learners are the intuitive-feeling types as opposed to CS and AS learners who are sensing-thinking individuals. Students who can stay along one track until completion will have no problems with TLE. This requires the learner to be relatively good at mathematics so as not to be frustrated by not being able to find the correct answer. With the exception of Beryl, all student participants liked the step by step problem solving approach. Jasper even thought that a teacher is better at teaching that way than the computer although the computer also proceeded step by step. This is why the students insisted a teacher is important. Jade also learned in orderly steps but felt that there were too many steps in some solutions. These participants seemed to be dominant CS or AS learners. All except Chalcedony stayed on the program. She found the questions too challenging. Beryl was frustrated because the steps laid out were not what he had in his mind and he preferred to work out the solution on his own instead of having the program dictate the next step. He mentioned several times that he needed to

write out his thoughts on paper and draw his own diagrams. He was not satisfied with keying in the right answer on screen or by following the program step by step.

I write what I think, but in the computer, it comes step by step for you. - Beryl.

TLE is not his preferred learning mode. His interest in music matches the profile of a typical CR or AR learner although he could also be AS or CS. Divergent thinkers will have difficulties accepting the fixed steps laid out by the program. In order to classify students into the various categories, students have to take the Gregorc style delineator tests. Since the participants did not take the classification test, this categorization is the personal assessment of the researcher and hence might not be accurate. However, Ross and Schultz (1999) found that if the learning mode of the student is not the same as the teaching style of the software, the medium becomes invasive and the student is left behind. This did happen and Beryl reported a sharp drop in grade while using TLE. The main reason for his opting out was because he wanted to work and write out his own solutions and draw his own diagrams on paper. He did not find the questions too difficult and even said that the pace was slow. He did not like the teaching style.

For the school year 1998-1999 and also 1999-2000, Pearl asked for volunteers to sign up for his class. He found that students who volunteered for the program are more motivated and they are able to adapt to the software. Ross and Schulz (1999) concluded that CAIs could not accommodate all learners

equally. Therefore, TLE should not be imposed upon students, they should be given an option to sign up for it. This echoes the fears of Sapphire who thought that while TLE was a good piece of software, he had reservations about implementing it on a large scale with all students.

Sapphire said that software usually accepts one unique answer down to the last decimal place as defined by the program. Many problems do not have a unique solution. The continuous use of such software may give the wrong impression that a unique answer always exists. Computer programs difficulty handling open-ended questions. Jade mentioned something very interesting when he said that the program tried to use numbers that give a nice answer. Clariana (1997) found that when using CAIs, learners become more active, less reflective and tend to become convergent rather than divergent thinkers. It is possible for programs to accommodate many different answers, but this means extra work for the content writer who must work out all the possible solutions. The content writer must also be a subject expert to be able to do that. This means extra production time and production cost for the company so it is usually not done. A way to accommodate open-ended questions is to give a small message when the desired answer is keyed in. The message should say: "Can you think of other possible answers to this question? Discuss with your teacher or friends."

Jasper, Chrysolite, Beryl and Jade would like to draw diagrams in the computer. Drawing their own pictorial representation of the problem is important

in the problem solving and learning process for many students. Riding and Rayner (1998) would classify these students as either wholist-imagery or analytic-imagery learners. They learn by drawing diagrams or building models. Under the NCTM guidelines for teaching mathematics, modeling and drawing of diagrams and pictures to solve a problem is part of the problem solving process. It reflects on a student's understanding of the problem. Diagrams help to organize information in a clear way so that a solution can be worked out easily. Currently, no commercially produced CAIs can accommodate this feature. For example, Macromedia authoring tools cannot read and validate (mark) a model or diagram drawn by a user using a mouse or other input device. TLE is authored using Macromedia tools. Other powerful authoring tools by companies like Assymatrix also cannot accommodate such features.

Producers of educational software have tried to find a suitable solution for this problem. The ideal solution is technically complex and, if ever programmed, the program would be rigid with serious limitations. One obvious difficulty would be that different students would draw different diagrams to represent the same problem. Commercial companies are not willing to take the risk. Hence, most multi-media CAIs draw diagrams for the user. Some programs present the user with several diagrams and the user has to choose the diagram that represents the problem accurately. The more ambitious programs simulate the drawing process. TLE draws the diagrams for the students and simulates the drawing process. Sapphire mentioned that one disadvantage of TLE is its inability to allow for modeling and drawing. Chrysolite said that he would not choose to use the

software again simply because he likes to write and draw pictures on paper. He has to look at his own diagram. He wished that he could draw in the computer and print out the diagrams as well. This is also on the wish list of Jade, Beryl and Topaz. Drawing in the computer might be possible, but for the program to mark and validate the diagrams, a technological breakthrough is required. Hence TLE is not suitable for students who depend heavily on drawing their own diagrams to solve problems and understand concepts.

However, this is related to the way in which TLE is implemented and the role of the teacher comes into focus again. Pearl mentioned note taking and the importance of these notes. Students who like to draw diagrams and pictures can do so in their notes. They can also write out their thoughts and alternative ways of solving the problem. If the teacher reads all the notes, a student's understanding of concepts will still be clear. Teachers can give a personal recognition of students' work when they read these notes. The final conclusion is again: The teacher is the key to determining the impact of innovation. The workload of the teacher does not become lighter with the use of computer guided learning.

#### Students With Outstanding Capabilities.

Results of the study suggest the usefulness of TLE when applied to a formal gifted program. The three above average students had no negative comments about using the software. Sardonyx even felt disappointed that TLE was not used again in grade 10. While Jade mentioned he wished that he could

draw diagrams on the screen, he was not particularly dependent on it. Like the others, he felt that the diagrams and simulations were sufficient. The three students were not too dependent on hands on manipulatives and were contented with on screen simulations. They preferred self study instead of group work. Topaz discussed his work with his friend. He took the initiative to work with one other person. Nevertheless, he was sure he did not miss group work.

These students are ideal candidates for the program. They are self-motivated, independent learners who prefer the abstract. They can go through the program without difficulties and at their own pace. These students want and are able to finish the lessons as quickly as possible. All of them felt that the program was slow in certain sections. Jade mentioned that there were too many steps in some solutions. Southern and Jones (1991), the editors of the book The Academic Acceleration of Gifted Children , define the word 'acceleration' to mean progress through an educational program at rates faster or ages younger than conventional. There are many types of acceleration options. It is not the intention of this study to go into the debate of academic acceleration. By using TLE, Jade was two years ahead of his peers. He enrolled with the distance education school but still attends grade 7 with his peers and took school exams. This arrangement eliminated many risks concerning academic acceleration. He was not removed from his peers and he went through the normal curriculum as well. The arrangement earned him recognition amongst his peers and increased his options for academic exploration. In schools offering formal gifted programs, students of the same age with outstanding academic capabilities are put through

a separate curriculum in addition to the usual lessons. The use of TLE software could be of help in these programs, as it saves time. This extra time can be used for other activities such as computer programming, solving challenging mathematics puzzles, projects, research or preparing for international mathematics competition. TLE should be implemented in formal programs for students with outstanding capabilities.

### Students' Morale and Attitude

Although students insisted they still hated mathematics after the program, evidence showed otherwise. Those who stayed on with the program, all felt a sense of accomplishment. Jasper, for example, found that learning with the software was fun and different from the usual classroom lessons. This difference must have improved her attitude towards mathematics. She was also concerned with the monitoring of students' work. This really showed her positive attitude towards the subject and her work. Carnelian hated mathematics and had no problems uttering "I hate math" more than once. He nevertheless admitted that he liked mathematics better when using the software. He learned better with the computer. He could learn at his own pace and he appreciated the freedom and the trust that he could monitor his own work. He liked to be in control of his own learning. He said that he found the problem solving questions to be helpful. He also spoke about the lack of monitoring of students' work. Chrysolite did not say that he hates math. However, he liked the fact that the software contained more information than the textbook and he could progress at his own pace. He said:

When the labs are available, I will demand to use it. - Chrysolite

This indicated that he wished to spend more time on mathematics and he is keen on mathematics.

Pearl found that some students who were difficult in the usual classroom were more on task in front of a workstation. This finding is consistent with literature concerning the effect of computers on students' morale and attitude. Kulik's (1994) meta analysis concluded that students like their lessons more when using computer software and students develop a positive attitude. Similarly Wenglinksky (1998) also found that when properly implemented, the use of CAI increases morale. Psychometrics Canada (MacNab & Fitzsimmons, 1998) reported that results are indicative that TLE program has a positive effect on student morale and attitude. 92% of 13 teachers surveyed felt that students' time on task had increased. Classroom observations commissioned by ITP Nelson (Beatt, 1997) also showed that students on TLE spent more time on task when compared to students in the traditional classroom setting. Perhaps, what is learned here is that students' words such as "I hate math" cannot be taken at face value.

#### Other Skills Acquired by Students

The most important impact the software had on students was that it gave them control over their own learning. All participants who stayed on the program had to learn independently. They were able to handle their own work and work out the solutions to problems on their own. This ability gave them great

confidence. The design of TLE, with its step by step approach to teaching and the blanks on every screen force students to learn independently. The way in which TLE was implemented as the main mode of teaching also required students to be independent learners. With the exception of Jade, it is unlikely that the other participants received parental guidance with their math while on TLE. All the participants said that their parents let them make their own decision as to whether they wanted to stay on TLE. No student participants other than Jade mentioned any parental guidance in math while on TLE.

It is obvious from the comments by students that they recognized the importance of homework and the monitoring of homework. This maturity is brought out by the fact that all of them took responsibility to do their work and commented on their friends who did not. Carnelian and all the teachers mentioned the note taking. Pearl emphasized that note taking skills were something students learned. Taking notes required students to read off a computer screen, pick out important points and write them down in their own words.

Reading and going through all these notes are important. They reveal a lot about students' understanding of concepts. Nelson Canada suggested in 1997 that teachers need not go through all the student notes as this would mean too much work. This is an example of how a company cannot give advice for every classroom situation. Publishing companies are far removed from the classrooms. Requiring notes helps the students became more responsible, even leading some to request more homework or teacher supervision and monitoring of work.

Pearl also mentioned that students tended to help each other willingly during lessons. All the students, including the above average students and students who opted to leave the program, agreed that the program was helpful in teaching problem solving skills. These findings are supported by Apple Computer's report on 10-years of ACOT research (Apple Computers Inc., 1995). Students develop the ability to explore and represent information in many forms. They become socially aware and more confident. They communicate effectively on complex processes and become independent learners and self-starters. They share their expertise spontaneously. Tapscott (1996) observes that this new generation of children and young people who grow up digital are independent learners and self-starters. They are able to research and pick up new knowledge from sources like the Internet and other forms of media. This results in lifelong learning. It is clear from the data that TLE, like any good CAI software, fosters abilities which are in line with the NCTM's (1989, 1998) objective to produce self directed learners who will value and use mathematics to solve real life problems.

In an article entitled "Evaluating the effectiveness of technology initiatives" Dede (1998) emphasized the importance of new skills needed by graduates in the work place. As the world shifts towards an economy that uses sophisticated people and tools to produce value added products, creativity and flexibility are vital skills. Tapscott (1996) calls this the digital economy. In this new economy, people must be able to form a cognitive partnership with intelligent machines. Problem solving skills are important. Dede calls them higher order thinking skills. Dede also wrote that students learning with technology tend to spend more time

on the subject. They are more motivated. Hence, these 'other' skills and attitudes developed as a result of the use of the software are most valuable. They can be categorized as 'life skills' preparing students for work.

#### Administrative Support, Teacher Determination and the Success of TLE.

Pearl's experience showed that the teacher must be determined to succeed with TLE. Besides putting in extra effort, he mentioned the support he had from his school's administration. They assigned the better labs to him and helped in time tabling and scheduling of lab usage. It is obvious that his school is a technology-rich school since every student had a workstation to work with. There was also a network administrator. He was given a budget and permission to renovate the labs to create a learner centered environment. Glennan and Melmed (1996) found that successful technology-rich schools usually physically redesign their classrooms, rethink their use of time and build partnerships between teachers, administrators, parents and students. There is explicit planning among teachers, school leaders, administrators, families and students to create an environment which focuses on the needs of the individual students.

#### Student Achievement.

There is not enough evidence to indicate that there was an improvement in students' grades. In fact, with the exception of three of the above average students, most student participants' grades fell when using the software. This, however, could be due to reasons not related to the software. Grade 9

mathematics is more challenging than grade 8; a fall in grade could be natural. A detailed and non-biased large-scale study is required to study the claims by Psychometric Canada Ltd (MacNab & Fitzsimmons, 1998) that there is an increase in grade. The Psychometric study report found that in all the participating schools, 66% of the TLE group scored 50% or higher on the math achievement test while 58% of the non-TLE group reached this mark. Students in this study sat for a math achievement test designed by Alberta Education. This achievement test was designed specifically to measure content of the grade 9 mathematics curriculum. Although this present qualitative study is very small and does not have a control group, there is surely no indication of a marked difference in grades between TLE and non-TLE students. If there were such a difference in grades, the teachers Pearl, Jacinth, Sapphire and Emerald would have mentioned it. The study did not mention students who cannot learn with the software and opted out. Nevertheless, Pearl reported that there was a big improvement in grade for some of his students. His experience is important as his school is successful with the implementation of the program. His school participated in the Psychometric study. Jacinth also noted that the weaker students tended to improve because they could go over the lessons again and again. The literature quoted in this study all found that the proper use and implementation of CAI results in better grades. Many critics have suggested that there is not enough evidence to show that the use of computers in the classroom results in an improvement in grades. Several meta-analysis such as the ones conducted by Kulik (1994), the Software Publishers Association's (1997) report

on the effectiveness of technology in schools, and the ACOT (Apple Computers Inc., 1995) report all suggest that the use of educational software do lead to grade improvements. To verify whether TLE results in better grades, a larger non-biased study with a control group is needed. Currently, the large-scale studies on TLE are those commissioned by the publisher of TLE.

### Geographical Locations

Kulik's (1994) meta analysis quoted by Glennan and Melmed (1996) found that computers did not have positive effects in every area which they studied. The average effect of CAI was almost zero for 34 studies on attitudes. The study of TLE's effectiveness by Psychometric Canada (MacNab & Fitzsimmons, 1998) concentrated on schools situated on the mainland in British Columbia and Alberta. The schools in Alberta were all either in Calgary or Edmonton. Schools in British Columbia were close to or within the city of Vancouver. The findings with regard to students' grade, attitude and morale were very positive. A check with Nelson Canada, showed that there were less than five schools in the Victoria and Saanich region who bought the software. Out of these, only two public schools implemented the program on a large-scale basis. One of them, Crescent High School, studied in this project, did not continue with the program. The other school implemented TLE in 1998-1999 but students complained to their teachers and parents about the program and many opted out. The situation seems to be highly similar to that of Crescent High School in 1997. Another school gave up after one term and refused to participate in this study. It is

possible that student and/or teacher characteristics in certain geographical regions suit the use of TLE more than in others. Other factors like availability of resources and administrative support could also affect the success of the program. In their web site (<http://www.ed.gov/Technology/Plan/NatTechPlan>), the US department of education cited an article by the National Information Infrastructure Advisory Council (1996). The article reported that leading edge technology districts in the USA are more likely to be located in affluent sub-urban communities. Perhaps this is also the trend in Canada. This would influence the successful implementation of technology in schools across the country.

## Chapter 6: Conclusions and Recommendations

### Conclusion

#### Implications Related to the Design of TLE

TLE is pedagogically sound in the sense that its features follow closely the principles of good instructional design. This fact can be seen in Chapter 2 where the key features of TLE match instructional design principles. However its use and implementation affect its effectiveness. The fourth objective of this study was to see how the design of TLE relates to students' preferred mode of learning and level of ability. Like other computer guided learning software, TLE is not able to accommodate all learners equally. Students like Beryl found the step by step approach restrictive. He had other ways of solving the problems and preferred to write his solution on paper. Nevertheless, TLE did make attempts to accommodate as many diverse learners as possible by solving the same problems in many different ways and by providing simulations and sufficient practice questions.

Chalcedony found TLE too challenging and Sapphire, who had been teaching for thirty years, believed that TLE is too demanding for weaker students. Although many research studies suggest that computer aided learning helps the low-achieving students, the set up of TLE requires the user to enter the correct response in every screen before proceeding. This can be discouraging and tiring for some students. For these students teacher mediation becomes crucial.

Nevertheless, Pearl and Jasmine did observe improvement in grades for some weaker students.

TLE is useful for above average students and students with outstanding capabilities. Such students will not be held back by their peers when using the software. It facilitates accelerated learning, freeing more time for these students to achieve their fullest potential.

### Implications for Teachers

The third objective was to study the implications for teaching strategies. The teachers' role is changed to that of a facilitator or tutor when using the software. Although they are no longer dispensers of knowledge, they are the most important variable affecting the effectiveness of the software. Teachers have to monitor individual student progress, assign and mark homework, mark student notes, plan for individual coaching and group discussions, ensure that students have access to computers and clearly communicate expectations to the class. The list of teachers' duties can go on; hence it should not be expected that the teacher's workload would become lighter with the use of TLE. The third objective of this study was also to find out if this extra effort on the part of the teachers is worth the effort. Pearl, who was successful with the program, had no regrets about putting in the extra effort. Means and Olson (1995) found that the successful integration of technology into the curriculum increases teacher job satisfaction and morale. In this study, only Pearl can confidently say that it is a worthwhile effort to make TLE work as the main mode of instruction. Due to this

small sample, generalizations are difficult. However, if the use of a CAI software such as TLE improves students' morale and attitude, increases students' time on task and help students become independent learners, teachers should find it worth the effort to integrate technology into their teaching.

### Implications for Implementation of TLE

In order to implement the program successfully, the teacher and school administration should believe that computer guided learning can make a positive difference in student achievement and attitude. Successful implementation requires support from parents as well. Commitment of support is needed to provide every student with a computer to work with, better labs with less technical problems, finances to renovate and upgrade the labs if necessary and the scheduling of lab usage. In the first year of implementation, teachers and students had to cope with changes in the learning environment. It is inevitable that many mistakes were made. The determination to continue with the program the following year is important because mistakes in managing the program can be corrected. Teachers are able to adapt to use the software successfully only in the second year of its use. Since not every student can learn with a computer as the main mode of instruction, it is highly recommended that students be given an opportunity to sign up for the course. Parental consent should also be sought. Ultimately, teachers and students will be able to use TLE with less effort. Teachers such as Pearl, Sapphire, Ruby and other teachers who use TLE successfully should keep a journal of their experience with the software through

the years. These journals could be collected and compiled; they would be useful in guiding future implementation of other computer aided instructional software. One of the goals of TLE is to assist educators in the transition to effectively integrating technology into their instruction. These journals by teachers would surely help to achieve this end.

### Implications for Students and the Community

The first objective of this study was to find out from the community's standpoint, if the large amount of money spent on educational technology is justifiable. TLE was found to have a positive impact on student morale and attitude. All student participants spent more time on mathematics when using TLE. In addition to using the software during math lessons, they also used the program after school hours if the computer labs were open or if they were allowed to take the CD home. In addition to all this, Pearl's students had to do homework. In the case of Jade, TLE was used as a supplement to his usual classroom lessons. Students had to take personal responsibility for their own learning; Jasper and Carnelian requested that either the teacher or the computer program to monitor students' work. They became self-directed independent learners. Chrysolite was really proud of the fact that he monitored his own progress and went through the lessons on his own. From society's standpoint, these are desirable attributes. Meta-analysis studies also indicated that proper use of technology improves student learning. With the world moving towards a

digital economy, the country cannot afford not to invest heavily in educational technology.

The second objective of this study was to find out if computer mediated learning any different from the usual classroom lesson. TLE offers an alternative mode of delivering lessons in the classroom. For the students in this study, this was drastically different from what they had experienced in their previous ten years as students. With the exception of the above average students with "A" grade for math, all others longed to have the teacher teach and comment on their work. For students like Chalcedony and Beryl, this drastic change was too much to cope with and they opted out of TLE. The second objective was also to give the students an opportunity to voice their opinions and suggestions about TLE. This they did by requesting monitoring of homework, tools to facilitate the drawing of their own diagrams on the screen, the ability to enter mathematical symbols and more hints provided by the program when they could not solve the problems.

#### Recommendations for Further Studies.

This study cannot determine if TLE is effective in improving student grades. In fact, comparing grades between TLE and non-TLE students does not necessarily mean that students' grades have improved. Without a study with a control group comparison of TLE and non-TLE students in grades 8 and 9, it is impossible to say if students using TLE performed better than those not using

TLE. The teachers did not notice any significant grade improvement in the students nor did they notice any marked difference between TLE and non-TLE students.

There seems to be an indication that geographical location influences the effectiveness of TLE. TLE seems more successful in large urban cities. Studies comparing achievement of both TLE students and non-TLE students, and examining the impact of geographical location on the effectiveness of TLE should be conducted.

#### Other Recommendations

The NCTM perceives mathematics as an investigative and active subject. Students are expected to solve realistic problems, usually in collaboration with others. TLE should take advantage of network and conferencing technology to facilitate group discussions. Since a TLE web site is already in place, a bulletin board for students could be set up where students from the various provinces could post interesting questions and suggested answers. Since there is a common curriculum framework, such an arrangement is feasible. Students could be encouraged to visit this bulletin board when they had the time or when they needed to solve some difficult problems. In the future TLE can be marketed in countries such as Australia, New Zealand and other parts of the world and students could communicate with their peers around the world. Teacher planned group discussions are still necessary. The development and maintenance of the

web site, bulletin board and conference facilities should be the responsibility of the Ministries of Education educational technology branches. Alternatively, the schools would have to pay a fee for the service.

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## APPENDIX B

### Human Research Ethics Committee Certificate of Approval



# University of Victoria

Human Research Ethics Committee

## *CERTIFICATE OF APPROVAL*

Principal Investigators

**Ivy Tan**  
**Graduate Student**

Department/School

**PFED**

Supervisor

**Dr. M. Uhlemann**

Co-investigator(s):

Kim Goek, Graduate Student

PFED

Title: **The Use of Computers in the Mathematics Curriculum**

Project No.

**108-99**

Start Date

**23 Mar 99**

End Date


**30 Sep 00**

Approval Date

**23 Mar 1999**

### **Certification**

This is to certify that the University of Victoria Ethics Review Committee on Research and Other Activities Involving Human Subjects has examined the research proposal and concludes that, in all respects, the proposed research meets appropriate standards of ethics as outlined by the University of Victoria Research Regulations Involving Human Subjects.

  
J. Howard Brunt,  
Associate Vice-President, Research

**This Certificate of Approval is valid for the above term provided there is no change in the procedures. Extensions/minor amendments may be granted upon receipt of "Request for Continuing Review or Amendment of an Approved Project" form.**

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## APPENDIX C

The effectiveness of Computer-assisted Learning:  
A case study of "The Learning Equation"

This research project is studying the effective use of computers in the mathematics classroom. Through an interview, you will be asked to share your experience in using "The Learning Equation" when you were in grade 9. You will also be asked to fill up a survey form. Your participation should require at most 1 hour of your time. The results will be published in a thesis for a master's degree project in the University of Victoria.

Your participation is completely voluntary and you can withdraw from the study at any time without explanation. You have the right to refuse to answer any questions you do not wish to answer.

Code names will be assigned and your name will not be attached to the published paper and will not be recorded in the data sheets or questionnaire. All the results of the interview will be locked in a cabinet. Signed consent forms will be stored separately.

Your interview will be audio taped and the tape will be erased once the researcher has recorded your sentences onto paper. If at any time during the interview you do not wish a particular response to be taped, the researcher will stop the audio taping. If you withdraw halfway in the program, no data will be used.

Whether you participate or not will have no bearing on your grades.

Thank You.

Researcher	: Ivy Tan	Supervisor	: Dr Leslee Francis-Pelton
Phone	:(250)4777899	Phone	:(250) 7217794

Researcher signature : \_\_\_\_\_

Student Name : \_\_\_\_\_

Student Telephone Number : \_\_\_\_\_

Student Signature : \_\_\_\_\_

Date : \_\_\_\_\_

## APPENDIX D

The effectiveness of Computer-assisted Learning.  
A case study of "The Learning Equation"

This research project is studying the effective use of computers in the mathematics classroom. Through an interview, you will be asked to share your experience in using "The Learning Equation" with your grade 9 students. Your participation should require at most 1 hour of your time. The results will be published in a thesis for a master's degree project in the University of Victoria.

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Thank You.

Researcher : Ivy Tan                      Supervisor : Dr Leslee Francis-Pelton  
Phone : (250)5929238                      Phone : (250) 7217794

Researcher signature : \_\_\_\_\_

Teacher Name : \_\_\_\_\_

Teacher Signature : \_\_\_\_\_

Date : \_\_\_\_\_

## APPENDIX E

Here are some of the common questions students are asked to talk about. Questions vary from student to student depending on the flow of the conversation.

Student interview questions.

1. How did you like learning with TLE?
2. What is the best feature of TLE?
3. Do you prefer TLE or the usual classroom lessons?
4. Which do you prefer, learning with the CD or textbook?
5. What new features would you like to see in TLE?
6. What do you think about the problem solving questions in the CDs?
7. What do you think about the hints that come up if you keyed in the wrong the answer?
8. Would you recommend TLE to a friend?
9. Do you like Math?
10. Did the use of TLE change your feelings or opinions about Math?
11. Do you think the practice questions in the CDs are sufficient?
12. If given an opportunity to use TLE again, would you choose to use it?
13. Do you believe that in the future, the computer will take over the teacher's job? If yes, do you like it?
14. Do you usually discuss your work with your friends in class? What about when using TLE?

## APPENDIX F

These are the question teachers and parents are asked. Discussion questions vary from interview to interview.

Teachers' and parent's interview questions.

1. What was your experience like using TLE?
2. Would you use TLE again?
3. Did you see any improvement in students' grades when using TLE?
4. Is classroom management easier in the computer lab or in the classroom?
5. Do you think TLE helped the weaker students?
6. Do you think TLE is a good piece of educational software?
7. Do you think the extra effort you put into making TLE a success is worth it?
8. How supportive is the school administration and how important is such support?
9. Did you get complaints from parents when using TLE?
10. What kind of students do you think will adapt best to TLE?
11. What are the shortcomings of this software?

## VITA

Surname: Tan

Given Names: Ivy Kim Geok

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### Educational Institutions Attended:

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Title of Thesis:

**The Effectiveness of Computer-Assisted Learning: A Case Study of the Learning Equation**

Author



Ivy Kim-Geok Tan

April 14, 2000