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MICROCOMPUTER BASED LABORATORIES AND PHYSICS LEARNING

by

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ABSTRACT

Education literature suggests that Microcomputer Based Laboratories (MBL) may indirectly enhance student physics achievement by offering several pedagogical and psychological advantages. Using data gathered from the Newfoundland Department of Education and a survey of 84 physics teachers, this exploratory research investigated the direct relationship between Microcomputer Based Laboratory use and high school physics achievement. The multiple regression analysis, which included control student factors (pre-treatment physics ability), classroom factors (teacher certification level, teacher years experience, teacher academic background, teacher microcomputer experience, extent of laboratory use, extent of instructional computer use) and school factors (school location, total school enrollment), indicated that at the present level of use, no significant relationship exists between Microcomputer Based Laboratory use and school-based or public exam achievement. The cause of this result was unclear. However, the survey data set revealed that only 55.3% of teachers were MBL users. This low level of use may account for the research results. Further multiple regression analysis of MBL use with classroom, school and teacher variables indicated that teacher-related factors (certification level, academic background, microcomputer experience, current instructional computer use, and current laboratory time) are significant predictors of MBL use.

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CHAPTER ONE

INTRODUCTION

The hallmark of any successful education system is provident, substantial and progressive change responsive to a varying social, economic, and moral environment. Significant change, however, is usually begun as a result of perceived inadequacies and unsatisfactory products. Recently, in Newfoundland and Labrador, the education system has been harshly criticized as uneconomical and unsuccessful. Low **C**anadian **T**est of **B**asic **S**kills (CTBS) scores and poor post-secondary results in science and mathematics (Crocker, 1989) combined with decreasing enrolments yet increasing cost (Williams, 1992) have demanded response. The government commissioned two comprehensive public inquiries, the Williams Report (Our Children, Our Future, 1992), and the Crocker Report (Towards an Achieving Society, 1989). These studies have provided the impetus and guiding philosophy behind Newfoundland and Labrador's ongoing education restructuring.

The Crocker Task Force on Mathematics and Science Education began in March of 1988 to investigate declining enrolment and poor achievement in post-secondary Mathematics and pnysical sciences. A major area of concern expressed in the report was the present science curriculum and the process of curriculum change. Crocker (1989) first pointed out that Newfoundland's science curricula were not very different from those of other Canadian Provinces. The courses covered a wide variety of topics within a discipline, however, they lacked any depth of treatment. Crocker (1989) concluded that rapid curricula reform was necessary to meet broader goals such as science literacy, science for citizenship, and science for critical thinking skills. He suggested a change in content so that science curricula cover fewer topics, while increasing their depth of treatment. The revised curricula should be Intended-Learner-Outcome (ILO) driven, re-emphasize the laboratory component, and increase students' understanding of the relationship between science technology and society (STS). Crocker summarized:

> *"Overall, it is clear that a major thrust in mathematics and science curriculum development is required. In science, in particular, nothing short of starting at the beginning and completely reworking the program throughout the system will suffice." (Crocker, 1989, p.192)*

More recently, Williams (1992) was particularly critical of Newfoundland's curriculum and the procedure by which it is reformed. The report indicated that, in an effort to combat drop-out rates, curricula had become less rigorous academically. It echoed Crocker by recognizing that, while all subject areas are important, a re-emphasis was required in Language, Mathematics and Science. More condemning, however, were William's observations of the methods of curriculum change and the quality of the outcome. Rather than being a progressive process, he described Newfoundland curriculum reform as reactionary, and dominated by the Department of Education. The "prescribed" curricula, he stated, did not meet local needs as identified by practicing teachers.

> *"In essence, the difficulty for many teachers is that they must accept the vision, content, and strategies of an established curriculum with too little opportunity for either personal contribution or local variation." (Williams 1992, p. 300)*

Williams concluded by recommending that all parties, Department of Education, school boards, and local schools, share responsibility in a renewed curriculum development process, one designed to change the role of the Department of Education from dictator to facilitator. This de-centralizing would allow all stakeholders to have input into curriculum design, each guiding the process, and ultimately being responsible for Newfoundland's school curriculum.

Reacting to these reports, the Department of Education has undertaken several initiatives to improve science curriculum reform and the quality of the result.

Curriculum Innovations

Several initiatives taken in developing the Physics 2214/3214 courses have tremendous potential. Most notably, the creation of the curriculum utilized much more consultation with practicing teachers and local specialists during every step of the curriculum development than in the past. The unprecedented level of involvement by local, experienced, knowledgeable people affected many aspects of the new courses, from method of organization to course materials.

Resulting from this bottom-up approach, the curricula started from a compilation of specific educational outcomes and then corresponding materials and methods were selected to accomplish these. Physics teachers were instrumental in producing the list of outcomes and selecting prospective materials. Furthermore, several teachers produced and authored all materials for the elective units. Rather than the usual piloting, which mainly consisted of minor debugging, the extensive two-year process was considered a chance to further develop the curriculum by receiving more input from physics teachers. Several teachers were given four potential texts, asked to use one, and then asked to evaluate it and the course. From these evaluations, and advice from several science education consultants, the Physics 2214/3214 curriculum established the first secondary science course to offer multiple texts. When the Department of

This new attempt at curriculum development (see figure 1.1) and the resulting innovations utilized in Physics 2214/3214 have produced a feeling of anticipation in the Newfoundland Department of Education, school boards, and teachers. The change in both method and outcome have produced a curriculum which might be expected to improve physics achievement. These arguments, however, may be over-simplified and not always be founded on established learning theory. For example, the use of MBL requires equipment that at first appears difficult to setup and operate, and is expensive. The time and school finances invested, however, may be worth the assumed educational gains. MBL equipment has the potential to replace many traditional pieces of physics equipment such as an oscilloscope, voltmeter, ammeter, barometer, and so on. Comparing the total cost of this equipment with MBL hardware, it is clear that the equipment required for MBL is a bargain. Moreover, learning to use one set of MBL equipment is thought to be easier than learning the numerous operating procedures associated with typical laboratory equipment. Students and teachers, their first time using MBL, may spend more time learning its operation, however, this same method can then be applied to

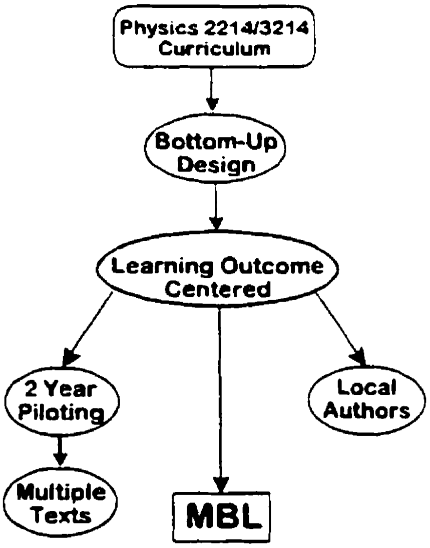


Figure 1.1: Innovation in Curriculum Development of Physics 2214/3214

dozens of different instrumentation in other lab activities. If traditional instrumentation were used, each operating instruction for each piece would have to be learned before any experimentation could take place. In summary: MBL is cheaper, allows for student control and flexibility, and ensures more time is spent experimenting instead of learning how to use various equipment.

Although this sounds reasonable, utilizing MBL requires operation of both hardware and software. Wiring and calibrating interfaces, setting necessary parameters on the computer software (use of the computer may be daunting in itself), and then learning the correct operation may be too much for an average student to master. Numerous laboratory activities may be required before students have a level of comfort at which they can explore their curiosities or complete an experiment without setup assistance. Cost comparisons between interface technology and "traditional" equipment may be misleading. "Traditional" equipment consists of stand alone instruments, while MBL require a complete computer system. Since MBL is a new technology, it is unlikely that many Newfoundland schools would have the necessary computer resources within their physics laboratory. These laboratories, however, would already contain some, if not all, the necessary equipment. This would substantially alter any cost comparisons. Certainly, the advantages of MBL are more complicated than it appears. We, as educators, may endorse MBL as a innovative and progressive step forward; however, the advantages of using MBL must be well researched and then evaluated.

Similar arguments can be established for the other unique attributes of the Physics 2214/3214 curriculum. Outcome oriented curriculum, bottom up curriculum design, local authors and materials, curriculum flexibility, teacher control, and the incorporation of MBL all have tremendous potential. As with MBL, we must critically examine the education literature for each, and carefully evaluate the outcomes.

Defining The Research Problem

It is widely stated that we are in the Information age. Data processing and telecommunication have now become a more important commercial activities than the once dominant manufacturing industry. Business, government, and the general public have all witnessed the overwhelming data manipulation power of the computer. Consequently, the assumption is often made that data processing advantages of computer use are transferable to the classroom and would result in similar product improvement, in other words, a better educated student. In fact, the general public in the past twenty years has been inundated by computer technology and are the beneficiaries of its abilities. Based on recent curriculum reform, the Newfoundland Department of Education appears eager to improve our schools (particularly science education) by utilizing the computer as a teaching resource. School boards, administrators, and teachers have responded by creating a need for technology in the classroom. This need is often based on personal experiences using technology, education literature and societal expectations of education progress, and not on clear evidence of the value of computer technology for learning. Despite these uncertain underpinnings, based on its public and professional popularity, governments have acted to integrate the microcomputer into curricula.

In Newfoundland and Labrador, the classroom integration of modern computer technology has been slow. Schools, in the late 1970's, lacked expertise and funding, and had very little assistance or directives from the Department of Education. Consequently, computer use was isolated and uncoordinated. Computers were predominantly used as administrative aids, with little consideration given to their potential in the classroom. In an education system with many needs, the computer was costly and, at best, unproven as a learning aid. In the early 1980's, however, coinciding with the birth of the microcomputer, its dramatic evolution, society's widespread computer use, and a growing body of education research on computer use, the Newfoundland Department of Education began tentatively planning the microcomputer's curriculum debut. This effort resulted in the first curricular use of the computer: a programming course first implemented in the 1982-83 school year, called Computer Science 2206. From this humble beginning, the Newfoundland Department of Education's interest in and employment of computer technology in schools has flourished. More recently, the Newfoundland Department of Education has not only encouraged computer integration into the curriculum of all subject areas, all grade levels (including special services), it has also advocated computer technology as an innovation of the future. For example: government, both federal and provincial, began funding Stem-Net (a computer network connecting teachers and students to numerous worldwide networks) and Distance Education (using the computer and telecommunications to offer a wider curriculum to remote areas). Computer emphasis in curriculum development has also changed focus, from an appendix added to developed curriculum to an integral component of student concept development. One of the best. and most recent. examples of this approach is the new Physics 2214 and 3214 curricula, where MBL is considered an important component.

Microcomputer based laboratory activities originate within, and arguably enhance, the practical component of instruction. It has been established that increased hands-on science or practical laboratory work improves science achievement (Freedman, 1997; Stohr-Hunt, 1996). If MBL enhances the practical component, its use should maximize the beneficial effects of hands-on science. therefore. improve achievement. The curriculum can be taught without MBL. however this teaching resource is on the cutting edge of science instruction and should improve classroom work.

Using this type of logic, the Newfoundland Department of Education began promoting MBL and inservicing teachers in its use in 1990. As part of this promotion, Physics 2214/3214 institutes were given (demonstrating MBL to all high school physics teachers) and each school board in the province was supplied with a complete package of MBL materials (that is: hardware such as probes, interface, etc., and software). This effort, followed by introduction of the Computer Technology 3200 curriculum (participating schools were given a $5000 hardware grant for MBL equipment) became the catalysts for MBL proliferation in Newfoundland. Today all high schools in Newfoundland and Labrador have at least one complete Vernier system (a particular MBL system). Although a sizeable amount of time and money has already been spent to introduce and supply these schools with the necessary MBL apparatus, more financial resources are required and many questions remain. This thesis will attempt to determine if student MBL use has any significant affect on physics achievement.

Unfortunately in this study both variables student physics achievement and MBL use. are difficult to measure in a valid reliable way and are influenced by many other school teacher and student factors which also must be considered. A teacher's education level or age, a school's student population or geographic location, and so on, are all variables that may interfere with any relationship between MBL use and physics achievement. For example; the data may indicate that students who are MBL users have higher physics achievement, however, these students may have a teacher who has attained a B.Sc. (major in physics) and this fact alone may cause the enhanced physics achievement. To understand whether MBL use will have an effect on achievement. this research will control for as many of the factors as possible.

To further develop the analysis between MBL use and physics achievement this research will attempt to determine what conditions are conducive to MBL use. If MBL users are more likely to have higher achievement in physics, delineating environmental conditions may assist other school systems to utilize computer interfacing. If on the other hand, no significant relationship exists between MBL use and physics achievement, a very probable explanation may be a low level of actual MBL use. If students are not exposed to a potentially powerful learning aid then it is equally important to determine the conditions that encourage MBL use. For example, if teachers, who are physics majors or avid computer users are more inclined to utilize MBL then this may affect future hiring practices. Any conclusion about the effectiveness of MBL will, therefore, be accompanied by results from analysis of MBL use as a dependent variable.

In summary, therefore, the research attempts to answer the following questions:

1. Does MBL use have an affect on student physics achievement?
2. What environmental conditions encourage MBL use?

Defining MBL Use

For this study, microcomputer based laboratory activity is defined as:

1. Student hands-on activity with both computer hardware and laboratory equipment.

2. The computer, using interfaces, measures various (at least one) physical parameter of a real-time event.

3. The measurements taken are stored in the computer's memory and may be manipulated instantly or at some later time (if necessary).

4. The computer allows students to display the collected data immediately; or after the physical event, in several formats, for example: tables, graphs, charts, etc.

5. The activity allows the student opportunity to re-try, re-test, or otherwise repeat the activity, or a variation of it, to further develop scientific concepts.

The specific subject matter, apparatus, and amount of data are irrelevant in determining whether an MBL activity is occurring. Simply, it is identified by the above attributes. However, deciding what level of student MBL use is considered reasonable so that they can be classified as MBL users is more problematic. Is a student using MBL during the physics course, if he/she employs it numerous times, for about 30 minutes each time, and only for laboratories involving graphing? Or; Is a student using MBL if it is used only twice, but extensively, for about three hours each time? Also complicating the measurement of student time-on-MBL is the size of student laboratory grouping. Must students using MBL be working alone with the equipment? Obviously, this rarely occurs with traditional science laboratories. If the students are not working alone, how can their level of MBL use be measured accurately? It is not the intention of this research to determine an acceptable amount of MBL usage and then use it as the measuring stick to classify the sample as "users" and "nonusers". Instead, and more important, the amount of student MBL use and its effect on physics achievement will be the focal point. If it is determined that present levels have no effect, then our level and method of MBL use must change if the arguments about MBL are to remain true. If, however, MBL has a positive effect on physics achievement, then gaining knowledge about the level of student MBL activity at which these positive effects are realized would be worthwhile and will require further clarifying study.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

Pedagogical Considerations

1. Does the Use of MBL Extend the Range of Student Investigations and Motivate Students?

The power of MBL sensors and the ease of use allows students to investigate more life-like and presumably more interesting activities (Rodgers. 1987. Thornton, 1987). No longer must a science investigation attempting to discover some novel aspect of theory be limited to carts and pulleys. Thornton's analytical 1987 paper. based on his experience developing MBL for middle schools in the United States. argues that students need to investigate the physical world around them in order to correct their "common sense" understandings of science. Instead of frictionless surfaces. collisions on air tracks. dropping point masses, etc.. students. utilizing MBL. can inquire into more realistic phenomena that they are concerned about and have experience with. Assuming students are interested in a topic. they would probably be motivated to learn more about the scientific theory underlying the activity. This type of student-science interaction coincides with Pines and West (1986) theories on misconception remediation.

Acting like scientists, in more genuine science activities, to inquire or make discoveries about the world around them, is a self-motivating endeavour (Thornton, 1987). The editors of the American Biology Teacher (issue Nov-Dec. 1988), Igelsrud and Leonard (1988), observed their classes, and gleaned from the literature, that students enjoyed using the technology and appreciated the opportunity to learn to use instrumentation that might be useful outside school. Matlock and Stafford (1989, p.316) discovered, from their experiences as first year college biology professors using MBL, that students actually competed for the role of operator. They conclude, "Such charisma rarely emanates from analog devices."

Besides a myriad of testimonies and personal observations from MBL users and their students, research also indicates that MBL is a powerful motivator. Stein (1987) was actively involved in gathering data from the piloting of the Computer as Lab Partner Project in a suburban California middle school. Her research entailed gathering information from a two-year qualitative study of 249 grade eight students using MBL. Stein was interested in classroom processes with respect to: teacher interactions, student-peer interactions, and student-MBL interactions. She considered three main questions: (1) How was MBL used in the classroom?; (2) What student and teacher procedures, processes and interactions characterized the classroom use of MBL?; and (3) What were the gains and benefits observed and what are the potential areas of difficulty identified for MBL use? From detailed teacher daily logs, numerous student and teacher observations, and random sampling of student evaluations Stein (1987) reported:

> *"...less than 2% of total laboratory time was spent by students on off-task episodes. Even the students identified as having learning or language difficulties persevered with the MBL system to troubleshoot and carry out labs." (Stein, 1987, p. 233)*

Like scientists, students using MBL are more likely to keep the purpose of the lab in sight, control and modify their investigations, respond to results, and propose "new" theories (Stein, 1987). Nachmias and Linn (1987), studying the same group of students at TERC, state that, while developing new theories may not be the specific purpose of some traditional labs, they often are the result of student discovery and testing.

Unlike Stein's qualitative study, Nachmias and Linn (1987) divided the two-year treatment into two phases. At the conclusion of phase I and at the beginning of and at the end of phase II, they administered the CEG (Critical Evaluation of

Graphs instrument) and recorded observational data throughout the treatment. The CEG measurement instrument was validated by a panel of science educators and two science education researchers; unfortunately no reliabilities were given. They concluded that MBL combined with proper instruction stresses the role of student as a participant in understanding the world. From student interviews they state:

> *"The metaphor that the fittest ideas survive fairly accurately describes how students come to understand the nature of heating and cooling in MBL. Students who test ideas against others come to revise their views." (Nachmias and Linn, 1987, p. 504)*

Utilizing MBL "discovery and testing" may be fun, an important consequence of its ability to minimize repetitive, mundane tasks. For example, a student may want to investigate the motion of falling bodies. MBL allows several experiments using different masses or objects which can be repeated in one laboratory session. The results can be manipulated and presented by the computer; arguably then, students spend more time at what they enjoy: exploring. With MBL, the bounds of student inquiry are extended so they may follow their own intuitions, whether successful or not. Utilizing MBL can, consequently, develop healthy, more realistic attitudes towards science and may ensure inquiry learning.

2. Are MBLs Effective Learning Aids for the Novice and the Underprepared Student?

Powerful instruments such as oscilloscopes or multimeters are often too complicated for novices to use, and so are not used widely. Various elaborate procedures, setups, and instruments would have to be employed in order to complete several different experiments. Initially learning to use one set of computer interfaces properly detracts from time spent on the actual experiments. Matlock and Stafford (1989) argue that an instructor need only familiarize students with a MBL system once, at the beginning of the course. In their experience:

> *"... students soon become comfortable with the consistent instrumental environment and can concentrate more on the experiment and less on the instrument..." (Matlock and Stafford. 1989. p. 316)*

Rakow & Brandhorst's (1989) overview of computer use in science asserts that elementary and junior high school students seem to have no difficulty mastering the software and making accurate measurements using the probes. Once the interface technology is mastered. Thornton (1987) contends, the better prepared student can work independently and pursue other questions.

Several researchers (Igelsrud and Leonard 1988. Brasell 1987a, Thornton 1987) also suggest that the managerial qualities of MBL are advantageous for the naive science student. During a typical MBL session, the software, in a predetermined method, will display important information and prompt the student for the necessary input (usually in a menu-type format). This may offer guidance to the student, since the software will not accept impossible data and will only proceed if responses are plausible. Accepting the data and continuing may act as a confirmation, or positive feedback, encouraging a tentative novice to continue. On the other hand, this software does not make the activity automatic - somehow isolating the student from the learning process - instead it only does what the operator demands. Stein (1987) reporting on student-labware interactions warns of potential problems caused by MBL software. From a myriad of observations of 125 middle school students enrolled in Computer as Lab Partner she concludes:

> *"While some students used menu options to enhance their control of lab procedures and data analysis. other students became 'lost' in the range of possibilities. or moved through the program inflexibly and often inappropriately...Even when students did know which menu sections to use, they did not necessarily know why they were using them. Many students. for instance. displayed misunderstandings of the function of calibration. though most students could follow the screen prompts to carry out a calibration." (Stein, 1987, p. 234)*

Brasell's (1987a) study on the effect of real-time laboratory graphing on learning graphic representations of distance and velocity was the first attempt to investigate the specific attributes of MBL that precipitate an improvement in graphing skills. Ninety-three students (seniors, average age 17.7) from seven rural schools in Northern Florida were selected as subjects. The experiment was a three-day event and took five weeks to complete. Students were divided into four groups; standard-MBL, delayed-MBL (they followed the same unit of work and method as Mokros and Tinker 1987, and Thornton 1986), control, and test-only. Extensive pre/post-tests were used (no reliability/validity indicators were mentioned) to assess performance in content, general ability, verbal ability, and graphing skill (i.e. to construct and comprehend). Brasell (1987a), in explaining the observed positive effect of real-time graphing, suggests that novices in a traditional laboratory exercise are unsure what features they should observe and are susceptible to "cognitive overload". The dynamic representation produced in real-time by the software may encourage the students to focus their attention on the changing plot or arouse their curiosity. The linking of the physical event to the graphical representation allows even the less able student an opportunity to construct meaning from normally incomprehensible data (Thornton, 1987). Rodgers (1987), in his descriptive essay based on his experiences, also points out that real-time graphs produced from MBL software have the potential to assist students who have poor drawing and graphing skills to exercise higher order conceptualizations associated with interpreting graphs.

For novice and underprepared students, therefore, the two prominent characteristics of MBL are its uncomplicated operation and its "lab-manager" abilities. Novices and underprepared students may benefit from these characteristics because they simplify and highlight activities which are normally very complex. With interferences such as complicated procedures or setups removed, laboratories can become better focused on their cognitive outcomes.

3. Can MBLs Encourage Inquiry Learning and Critical Thinking Skills?

Eliminating the drudgery of data collection and manipulation, computer interfacing allows a laboratory exercise to be partly automated. The software simultaneously displays the explicit, graphic results as the experiment is taking place. Several pedagogical advantages arise from the immediate visual feedback of a physical event. The improvement of critical thinking skills and inquiry learning is one such benefit.

Imagine, for example, a grade twelve physics student named Debbie, an experienced MBL user, investigating the motion of a pendulum (see figure 1.2). She decides to begin an experiment by measuring the change in displacement (traditionally a very difficult task, made easy using MBL) and immediately finds that the resulting graph is sinusoidal. Continuing to analyze this motion, and a few keystrokes later, she realizes that the velocity and acceleration of the moving plumbbob are also sinusoidal! Quickly, she decides to check these results by varying the mass of the plumbbob, the length of the string, and the distance from the centre from which she releases it. The results? The shapes of the three graphs do not change. The teacher asks Debbie, "What is it about the motion that causes the shape on all three graphs?" She responds that the motion repeats over time. The teacher suggests she test her hypothesis. Debbie disassembles her pendulum and sets up a mass on a spring; the measurement technique is the same, so results are generated quickly - the investigation continues.

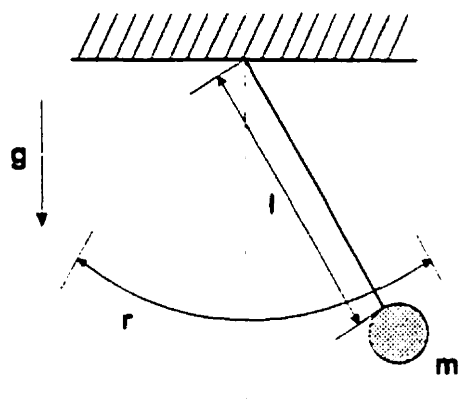


Figure 1.2: Simple Plumbbob experiment

Debbie, utilizing the MBL, had the ability to direct her own investigation. Thornton (1987) observed the rapid, versatile interface technology allowing students to react to results, and then modify, or further investigate, hypotheses. Thornton (1987) concluded that students can answer their own "what if...?" questions using fundamental tools similar to those scientists use. They can then reshape their original hypotheses, test new hypotheses, and display new results i.e. they can conduct incremental modeling.

MBL may also present an opportunity for Debbie to be more creative, because essentially the same equipment and methods were used. Falsifying or verifying theories need not be as limited by the availability of traditional laboratory apparatus, or the students' ability to use it. Easily generated outcomes from various student experiments may facilitate analysis of the data. The power of computer data collection opens new opportunities, encouraging realistic problem-solving and critical thinking. Rodgers (1987) proposes:

> *"With less emphasis on linear graphs, perhaps students can cultivate a circumspect and honest attitude towards results where there is less concern for arriving at the right answer and more curiosity towards making sense of the data, recognising similarities, differences, and generally seeking out the significance of data." (Rodgers, 1987, p. 222)*

The above activity illustrates what Kapisovsky (1990) suggested based on her experiences at TERC: with the tedium of data collection and the delay of outcomes removed, students are free to explore, measure and learn from the physical environment. Removing unprofitable tasks, such as setting up equipment, learning to collect data, and so on, gives students more time to focus on developing major concepts. These trivial activities could undoubtably sidetrack attention from the cognitive goals of the investigation. Igelsrud &

Leonard (1988) claim that rather than adjusting apparatus, students could be changing variables, generating hypotheses, or processing numerous other higher order activities.

Current research in this area seems to substantiate these claims. Friedler, Nachmias and Linn (1990) completed a very detailed investigation in which they attempted to answer the following:

> *"(1) How do students acquire observation and prediction skills from the MBL curriculum? (2) Are the cognitive demands for the observation group different from those for the prediction group? (3) Does learning observation and prediction help use other scientific reasoning skills?" (Friedler, Nachmias and Linn, 1990, p. 173)*

Their research involved 110 eighth grade students studying physical science using a MBL temperature probe and an ingenious content-free computer game. Extensive observation and written testing (DFT - Discover Final Test - no report of validity or reliability and so the results are questionable) monitored student progress. From their observations Friedler, Nachmias and Linn (1990, p.174) pointed out that the immediate feedback provided by the computer about the physical event encouraged students to use the evidence to select the most appropriate paths in the problem-solving process.

4. Do MBLs Encourage Learning From Peers?

The fundamental nature of manipulating computer interface technology encourages students to work independently in the laboratory. As stated before. this independent work produces results during the lab time, not hours. or even days later. Thornton (1987) proposes that having the results with other classmates present would be conducive for discussions between lab partners, and lab groups. Stein (1987) observed that:

> *"...instances of disparity were successfully diagnosed and cooperatively remediated. One feature contributing to this was students propensity to monitor and compare their results to others'. which was made possible by the fact that results were displayed graphically on the computer screen." (Stein, 1987, p. 233)*

Stein (1987) goes on to describe how students formed "consulting groups" to solve problems, giving them another avenue to find help besides the often busy teacher. Stein (1987) concluded that in her study student cooperation (i.e.. peer interaction) was an essential factor in stimulating students to draw thoughtful conclusions from laboratory activities.

MBL has the potential to radically change the use of laboratory time. Traditionally the lab period is used to setup an experiment and collect data. The student, outside school time, produces results and usually receives meager assistance in solving post-lab questions. Alternatively, the use of MBL encourages peer tutoring, which has been shown to be an effective learning aid. This also lessens the pressure on teachers, allowing them to concentrate on acute learning difficulties that may develop.

5. Are MBLs an Effective Means of Teaching Graphing?

Graphs are part of a symbol system, similar in some respects to language, that scientists use as a central means of communication. Mokros and Tinker (1987), in the introduction of their quantitative study, The Effect of MBL on Children's Ability to Interpret Graphs, state:

> *"Graphing constitutes a key symbol system in science because it summarizes the covariance of two or three variables over a large number of measurements. It also allows us to use our powerful visual pattern recognition facilities to see trends and spot subtle differences in shape." (Mokros and Tinker. 1987, p. 369)*

Consequentially, graphing skills are critically important to understanding many topics in science. Researchers such as Shaw, Padilla, & McKenzie (1983, cited in Mokros and Tinker, 1987) have established a link between students' graphing skills and their ability to understand scientific concepts. Inadequate graphing skills are a major impediment to comprehending scientific theories.

Mokros and Tinker (1987) have studied in great detail the types of complications that cause poor graphing skills, and the effectiveness of MBL in improving them. From their preliminary study (clinical interviews of 25 seventh graders), which has become the starting place for numerous MBL research activities that followed, they found two major graphing misconceptions: (1) a strong tendency to view graphs as pictures rather than symbolic, relational representations; and (2) indications of a slope/height confusion. Brasell (1987a) found that 1/5 of rural senior high students were seriously restricted, by inadequate graphing concepts, in their ability to understand graphs. Mokros and Tinker (1987), in a three month quasi-experimental study (using a pre/post-test combined with 15 minute interviews), discovered that seventh and eighth grade students, after a five-day treatment of MBL, showed a significant increase in ability to interpret and use graphs. They state, "...MBL instructional strategy appears to extinguish the (two misconceptions) quite easily.". So easily in fact, Mokros and Tinker question whether these deficiencies were actual misconceptions, since they did not seem to resist proper instruction.

Considerable research has been done to substantiate Mokros and Tinker's results. Linn, Layman and Nachmias (1987) studied 240 eighth graders from a suburban middle school in a treatment/control group experiment. They administered a pre/post-test of 21 multiple choice items designed to evaluate the student's "chain of cognitive accomplishments for graphic representations" (p. 491). Linn, Layman and Nachmias (1987) concluded that MBL was successful in teaching students about graphing, improving their ability to identify graph trends and derive the meaning of the information presented. After using MBL, students were less likely to misconstrue graphs as pictures, instead seeing them as dynamic representations. Ahtee and Ahtee (1991) stressed the importance of student activity when creating motion graphs on MBL. They found that in order to develop graphing skills, students need to be explicitly led to connect the graphs with actual motions, for example, to recreate what a graph means. Brasell (1987a) confirmed that even after a short exposure to MBL (only one 40 minute session) slope/height confusion was easily resolved as compared to "traditional" instruction. She studied the effect of real-time laboratory graphing on learning graphic representations of distance and velocity in a three-day experiment. Students were divided into four groups; standard-MBL. delayed-MBL(they followed the same unit of work and method as Mokros and Tinker 1987, and Thornton 1986), control, and test-only. Extensive pre/post-tests were used to assess performance in content, general "ability", verbal ability. and graphing skill (i.e. to construct and comprehend graphs). Brasell (1987a) further concluded the salient attribute of MBL that enhances graphing comprehension and ability:

> *"Real-time graphing...accounted for nearly all (90%) of the improvement within the standard-MBL treatment relative to the control. At no time was the*

> *performance of delayed-MBL students significantly superior to that of students in the control treatment. These results indicate that the real-time graphing feature of the MBL was effective in improving graphing performance." (Brasell, 1987a, p. 329)*

More recent research utilizing better design and methods seem to confirm these early results. Adams and Shrum (1988) completed a clinical study of 20 students enrolled in general biology classes in which students were first grouped according to ability (using GALT - Group Assessment of Logical Thinking) then divided into treatment or conventional groups. All performance measures were validated (construct and criterion) and each student was interviewed using an open-ended version of TOGS as a guide. Their results show that students using MBL exercises did outperform ($p < 0.10$) the conventional students on graph construction tasks as measured by I-TOGS construction subtest (KR-21 reliability 0.80). Adams and Shrum (1988) pointed out, however, that they had great difficulty teaching graphing skills using MBL. They suggested that a third variable, cognitive development of student, had a tremendous influence on outcomes from MBL, and so should be studied further.

6. Are MBLs an Aid to those with Science Anxiety (particularly female students)?

It has been argued that three components of computer interfacing: (1) ease of use, (2) student control, and (3) interesting investigations, improve negative attitudes associated with the science laboratory. Thornton (1987) contended that students who have had poor experiences with science find MBL rewarding when they control their own investigation and succeed. An important benefit of autonomy when using the computer is the student control - computer response interaction between software and the student. Rakow and Brandhorst's (1989) cited several computer attributes - inability to disparage (and so "discourage" or "intimidate" the novice or the underprepared), infinite patience (to the benefit of the "slow learner"), and prompt response to student commands - all of which may likely heighten student enthusiasm.

Thornton (1986) and Brasell (1987b) both reported that women's attitudes towards science improved dramatically after using MBL. Thornton, in his 1986 work, discussed the use of one session of MBL in two very different situations: a sixth grade classroom in a public school and two college physics courses at Tufts University. From "...class discussions and test results...", and, "...his and others experiences..." (no other elaboration), Thornton (1986) states five educational advantages of MBL. Four of these:

> *"(1) MBL versatility gives students a wider range of potential experiments; (2) reduced drudgery allows students to focus on meaning and real inquiry; (3) ease of data manipulation provides good basis for hypothesis formulation; and: (4) MBL is an effective means of teaching students scientific symbol systems such as graphing" (Thornton, 1986, p. 5)*

have either been tentatively accepted as logical, or initiated further research. The fifth (p. 5): "Preliminary evidence indicates MBL can work well with women as well as men and may well be an aid rather than a hindrance to those with science anxiety." has gone largely unresearched or treated as an aside to research in other directions.

Brasell (1987b) studied sex differences related to graphing skills in MBL and suggested that MBL improved female students' lack of graphing ability (they gained on the males), and so they had greater success. This research, however, is uncertain since no reliability/validity data was reported and, combined with the short treatment period (a single class), the results are tentative at best. Stuessy and Rowland (1988) continued to consider gender differences and the effect of MBL in their pre-/post-test study of MBL on grade ten biology students. Measurement techniques were not specified and potential confounding variables were not considered, therefore, it is appropriate for the authors to comment on the results:

> *"...gains scores in graphing skills were higher for girls than for boys indicates that further research is needed regarding how laboratory activities, including MBLs, can enhance graphing skills in females." (Stuessy and Rowland, 1988, p. 21)*

More recently, Berge (1990) has completed specific research, much more rigorous than previous attempts, dealing with the gender issue. Berge, studying the role of MBL in acquiring science process skills, utilized 245 seventh and eighth grade students in 12 science classrooms in three schools. The treatment period was 10 science classes for 50 minutes each and results were collected in a pre-/post-test design. The lessons were created from, and tested by, past research (McLeod, 1989) and the measurement instruments used were the standardized TIPS and TIPS II (Test of Integrated Process Skills). Using MANOVA (multianalysis of variance) Berge (1990) concluded:

> *"...no significant differences between males and females in learning science process skills ...the results of this study ...generated gender-neutral achievement outcomes in science." (Berge, 1990, p. 759)*

Beichner (1990) concurred with this outcome in his study of the effect of simultaneous motion presentation and graph generation.

In an effort to investigate Brasell's (1987a) research regarding the real-time graphing ability of MBL, Beichner designed a 2x2 balanced experiment. The subjects (237 high school and college students) were randomly divided into four groups: (1) traditional lab techniques and students viewed the motion (student group were first demonstrated a moving abject then given stroboscopic pictures of the event to analyze); (2) tradition lab techniques where students did not view the motion (no demonstration, only stroboscopic pictures were analyzed by the group); (3) MBL (videograph) lab techniques where students viewed the motion (motion was first demonstrated to the group and then video of it ran along with; i.e. on the same computer screen; production of corresponding graphs/data); and; (4) MBL (videograph) lab techniques where students did not view the motion (students were shown a video of the motion along with production of corresponding graphs/data only). The treatment lasted for one class session combined with one two-hour laboratory class; during the same week pre-test, treatment, and post-test were administered. Performance measurement was done utilizing TUG-K (Test of Understanding Graphs-Kinematics, KR-20 reliability coefficient of 0.73) and follow-up analysis was exacting (based on ANCOVA). One of Beichner's conclusions:

> *"...neither gender learned more than the other. as evidenced by an analysis of the difference between pre- and posttest scores (the change score), F(1. 219) = 0.84. p = 0.36." (Beichner. 1990. p. 8)*

indicates that at the very least MBL was gender-neutral, and so, has the potential to provide equal science education for both males and females.

The debate continues; however, and the notion of "placing women on an even playing field" with men in science still intrigues MBL proponents, and most certainly, all science education researchers. If MBL has this ability, it must be established and developed. Once on a level with other classmates, female physics achievement may improve, and therefore, females may have a more favourable outlook on science.

Psychological Justification

1. MBL Is Multi Sensory.

Students taking part in microcomputer-based laboratories experience numerous sensory stimulations from an event associated concurrently with the graphic results. For example; a student using MBL to study sound may use the computer to plot sound waves from a guitar string as he/she holds different frets. During this investigation the student; "hears" the changing sound, "feels" the string vibrate, and "sees" both the changing results on the screen and the phenomena causing it. Students and/or teachers maximizing the computer's versatility can further customize the output in a manner that they feel most untroubled with. For example, a multitude of different tables or graphs, text, and even animation, can be used to present the results of student activity that better facilitate learning. The visually changing results are reinforced by the multimodal experience of the fluctuating event. In explaining MBL effectiveness in cultivating graphing skills Mokros and Tinker (1987) state:

> *"This multimodal approach to learning enables students to use their 'strong' intelligences or learning styles and at the same time encourages them to build upon learning modalities that are weak." (Mokros and Tinker, 1987, p.381)*

Beichner's 1990 research supports the claim that productive learning from MBL is a result of more than just "seeing" the physical event and the graphical representation in real time. Testing this particular attribute of real-time graphing, he found that there was no significant difference between the four treatment groups ($F(3, 218) = 0.775$, $p = 0.509$), although there was significant learning overall ($t = 4.86$, $df = 221$, $p < 0.001$). Beichner supports Mokros and Tinker's (1987) arguments:

> *"The Videograph technique can present replications of motion while generating graphs, but other than determining the rate of animation, students cannot control the motion. This ability to make changes, and then instantly see the effect, is vital to the efficacy of MBL kinematics labs. The feedback appeals to the visual and kinesthetic senses. A simple visual juxtaposition of event images and graphs is not as good as seeing (and "feeling") the actual event while graphs are being made." (Mokros and Tinker, 1987, p. 811)*

"Feeling" the actual event implies seeing, hearing, touching, etc. which substantiates Mokros and Tinker's (1987) theory of multi-sensory experiences facilitating learning.

Appealing to the particular "strong" senses of students is again argued by Friedler, Nachmias, and Linn (1990) as an important benefit of MBL activities. They proposed that better cognitive outcomes (such as graphing skills or conceptual development) are achieved when students reinforce their physical experiences with tabular or graphical results. They further suggest that offering a variety of choices in representation that would appeal to individual students would improve student achievement, since the tabular or graphical results should emphasize prominent information. This emphasis would explicitly and clearly link student experience with symbolic representation.

2. MBL Pairs, in Real Time, Events with their Symbolic Representations.

The greatest potential for educational benefit from MBL is its ability to produce graphic representations of physical events simultaneously, thus generating immediate feedback. Many researchers (Brasell, 1987a, Igelsrud & Leonard, 1988, Thornton, 1987, Mokros & Tinker, 1987, and Layman, 1991) have studied the effects of real-time graphing and found that it helps bridge the gap between the concrete experience and the formal symbolic representation.

A typical high school biology class has approximately 1/3 concrete thinkers, with the vast majority being transitional (Lawson & Blake, 1976 cited in Igelsrud & Leonard, 1988). With immediate illustration of relationships between variables, data becomes more meaningful, especially for transition students (Igelsrud & Leonard, 1988). Brasell (1987a), trying to distinguish these effects, investigated the significance of the immediate feedback feature. She compared standard use of MBL with delayed-use (using MBL, however, presentation of results were delayed slightly) and found instantaneous feedback was crucial; even very short delays drastically affected concept learning. In fact, delayed-MBL students showed no better performance than the control group (no MBL). Further quantifying her results, MBL real-time graphing accounted for 90% of the improvement in learning of kinematics graphs in high school physics classes using MBL compared to traditional classes (Brasell, 1987a). The question remains, however; why does immediate feedback from an event augment student learning? Brasell (1987a) offers this explanation:

> *"...real-time graphing allows learners to process information about the event and the graph simultaneously rather than sequentially....If the initial entry and processing of information in the brain takes place in short-term memory. then real-time graphing may allow rapid cognitive linking within short-term memory and thus increase the likelihood of the linked information being transferred to long-term memory as a single unit." (Brasell, 1987a. p. 386)*

She goes on to claim that the clear, simplified connection of real-time graphing can, and does, take place in the limited short-term memory.

The notion of freeing students from interfering cognitive stresses, such as basic mathematical computation. use of complex equipment, etc.. so they can focus on concept development has been postulated, and has been studied further. Pea

(1985) argues that computers not only amplify mental capability (in other words help transcend the limitations of the mind) they also restructure the thinking process. For example, while using software to aid in algebra equation solving, there is an alteration of the cognitive skills necessary: error-free computations and operations on numbers and formulas are no longer as important as the higher mental activities associated with problem solving. He suggests that this reorganization of cognitive skills is not only necessary in today's information society, but, is also the cornerstone of successful computer use in education.

It seems this reasoning is sound, but does MBL remove these cognitive stresses and alter the focus of laboratory learning? Research referred to above regarding graphing skills illustrates its effectiveness in skills development. When comparing a computer game (Discover, a content-free problem solving game) to a "real" MBL investigation of the concept of temperature, Friedler, Nachmias, and Linn (1990) found that small loads on limited short-term memory enabled students to employ efficient problem-solving strategies.

> *"...the Discover game puts a relatively small load on the limited capacity of the short-term memory. thus enabling students to employ efficient problem-solving strategies. The fact that just one-third of the students were able to control variables in the subject-matter-related test, compared with the two-thirds that did so in Discover test. lends support to the argument about the advantage of low memory load." (Friedler. Nachmias, and Linn. 1990. p. 188)*

Layman (1991), illustrating the effect of MBL on teaching the Ideal Gas Law, proposes that conceptual development (or change) can occur successfully when intermediate demands are removed and observations are linked to outcomes. In his paper, presented at the International Symposium on the Evaluation of Physics Education (Helsinki, Finland, June 25-29, 1990), he combined the research of Thornton (1987) on MBL, with Arons (1989) teaching/learning procedures in a logical thought experiment based on his past experiences working at NSF developing MBL activities and inservicing teachers.

An ongoing study by Nakhleh and Krajcik (1991) indicated that strong understanding of acid-base concepts and remediation of weak models of matter are intensified as a result of MBL. Their qualitative research involved constructing concept maps from samples of learners involved in several presentation methodologies (of the concepts acid, base, and pH). Learners employing MBL applications produced overall more complex and diversified concept maps. They proposed that MBL allows students sufficient time to contemplate, on a molecular scale, what is happening; to access their long-term memory; and therefore, restructure their knowledge.

The shift in cognitive activity and outcome that is a result of MBL use seems to be associated with its ability to remove/limit mundane tasks and link, in real-time (possibly in short term memory), the physical event with symbolic representation. Further research, however, is needed to confirm these arguments and preliminary studies.

3. MBL Activities allow for Frequent Repetition of Diverse Events.

Throughout this paper, various sources (Mokros and Tinker, 1987, Brasell, 1987a, Thornton, 1987, etc.) state, or strongly imply, that MBL characteristics, such as speed and simplicity, positively influenced the pedagogy and psychology of science education. It would be remiss to overlook MBL's influence on one of education's seasoned principles: Practice makes perfect. Increased laboratory experience, obtainable from MBL, would allow students to formulate powerful mental templates (Linn, Layman and Nachmias, 1987). They explain:

> *"We know that learners construct their understanding of the world. They often take their first example of a particular phenomenon as a prototype for that situation and then use it to interpret the next example." (Linn, Layman and Nachmias, 1987, p. 247)*

Developing these prototypes would enhance a student's abilities to work independently and problem-solve. Linn, Layman and Nachmias (1987) demonstrated that frequent repetition of MBL activities seemed to assist production of mental guides (the guides were more dominant than before treatment) for motion, velocity, temperature and acceleration graphs. In their conclusion they stated:

> *"Most of the students came to the course with incomplete temperature and motion templates. Viewing many graphs presented on the computer screen helped students to build graph templates for heating and cooling curves." (Linn. Layman and Nachmias, 1987, p. 252)*

Within science teaching, the need may also arise to utilize the lab for demonstration purposes. For example; a student may not "believe" that a chemical reaction can be endothermic. Pines and West (1986) assert that students may not correct misconceptions because they witness one example that contradicts, when in their everyday experience they see numerous that do not. In such a case it may be necessary to "prove" endothermic reactions to the student by repeating an investigation using various examples. The high quality and quantity of data available from MBL would make such remediation elementary and an easily employed educational technique. Adams and Shrum (1988) showed the importance of practice when their results ($p = 0.05$) indicated that conventional laboratory exercises allowed students to practice graph construction skills, thereby resulting in higher student achievement on graph-construction tasks. The MBL group constructed fewer graphs (the computer constructed them) and so. construction of graphs achievement was lower in MBL group. With regard to graph interpretation, however, the MBL group outperformed the conventional group (an effect size of 0.48). This would seem logical since the MBL group spent less time constructing graphs and more time interpreting them.

Summary

The present MBL related literature can certainly be described as supportive. Research suggests that educational benefits of MBL are dependent upon a definite set of abilities that improve some laboratory activities. During a MBL session, the computer hardware and software:

1. has a level of management. The computer requires information in a particular format and sequence. It also determines the range of output possibilities.

2. removes "menial tasks" associated with traditional laboratory activities. Whether repetitive calculations or manual graphing have educational benefit is open to debate. Removing them, however, allows more student time to be used for other activities.

3. provides instant feedback. During an MBL activity feedback is given in an uncritical, unsupportive manner throughout the activity and as output.

4. is a versatile tool of information gathering and analysis. A wide range of experimental variables may be measured utilizing one set of equipment and instructions. Analysis and presentation of results is limited by student ability and complexity of software.

Research supports the idea that these abilities have many possible effects on a traditional laboratory activity. The microcomputer based laboratory, with a wider range of laboratory topics, shifts student efforts to higher order processes. These processes, such as analyzing and experimenting, are more science-like in method and subject. The real-time, useable feedback and guidance that MBL offers potentially provides students with the opportunity to produce their own results from their own methods. Having students replicate the scientific method motivates (as it does real scientists), encourages cooperation, and, develops inquiry and critical thinking skills. Laboratory-related conclusions may result from repetition of experimentation, or mathematical associations which both require detailed analysis of variables (and usually include graphing). MBL seems to ameliorate these activities, therefore, students utilizing MBL have stronger understandings of graphical data and what it implies. The research also indicates that novices, underprepared, or otherwise less capable students, benefit from the noncritical interaction with the software. The programming also offers a level of guidance that possibly reassures students to continue. If, while utilizing MBL, mistakes are made or results are inappropriate, repeating the laboratory may be less of a punishment, since any new procedures such as gathering more data or changing method of analysis are quick and supply immediate feedback.

Do these beneficial effects on laboratory activities translate into a deeper understanding of the subject matter investigated? Does MBL have a significant effect on a student's science achievement? The answers to these questions remain untested and tentative. Research cited above by no means establishes a strong, significant relationship between MBL use and student achievement.

It is important to recognize that much of any completed supporting research may already be obsolete. The growth of technology (both hardware and software) and its proliferation through schools means MBL and its capabilities have changed dramatically in the past five to ten years. Subsequent development of microcomputer based laboratories combined with the explosion of the information age would colour conclusions involving older technologies. In fact, much of pre-1990 research may be discounted since MBL capabilities then were rudimentary compared to more modern versions. Moreover, the existing body of literature pertaining to MBL is not capable of supporting a positive relationship between MBL and science achievement. Nakhleh (1994) in her review of MBL research criticizes:

> *"Many of these studies allowed a very short time for treatment, and these treatments were especially designed modules which bore little relationship to the total curriculum or were treatments experienced by individuals in a clinical setting, that is, no instruction. Many studies used only one type of probe, and assessments were sometimes multiple choice tests, which were narrowly focused on achievement rather than explorations of the students' understanding." (Nakhleh, 1994, p. 378)*

She continues her critique by noting that research has also been largely limited to middle school settings investigating MBL and graphical understanding. Conclusions based on specific, short time treatments, limited to middle school students cannot be extrapolated to overall curriculum achievement for all science students. Nakhleh (1994) recognized six requirements for future research: 1. Longitudinal studies where MBL is integrally involved in the entire "real-world" science curriculum; 2. Thorough research in the secondary, and higher, levels with special attention given to gender differences; 3. Research focused on how students construct knowledge using MBL and how this affects interpretations of physical phenomena; 4. More research into the connections students make between the MBL graph and the event that it represents; 5. Research investigating different probes; and; 6. Research of MBL activities affect on students' attitudes towards science and how this affects motivation and understanding of scientific experimentation.

The need for a broader, long term study, where MBL is integrated into an existing curriculum is evident. Student science achievement, however, may depend on a myriad of variables, one of which may be MBL use. To properly understand MBL's affect on science achievement, research is also required into the relationships between MBL use and other confounding variables.

CHAPTER THREE

DESIGN AND PROCEDURE

Introduction

Research pertaining to physics achievement has produced a lengthy list of conditions and environments that influence achievement. Determining relationships among the numerous factors is difficult. It is important. however, to do so if the ultimate goal is understanding the fundamental attributes that enhance physics achievement. For example; in this research it may be realized that MBL use does not improve achievement for all students; only students who are taught by inexperienced teachers; or students in large schools; or rural students; and so on. Choosing the correct variables and experimental design to study the effects of a particular treatment, therefore. is essential if conclusions are to be considered valid.

Research design and selection of descriptive variables for this study was greatly influenced by the type and availability of data. The Newfoundland Department of Education provided an extensive collection of school and achievement statistics pertaining to 1771 secondary students. The data source, however, did not include information concerning students' MBL use or related classroom experiences pertinent for delineating the treatment variable. This chapter explains decisions made regarding the method of collecting this information, then reviews the complete database available. All variables available will not be included in the research design because it was beyond the statistical ability for this sample size, and some are unrelated to treatment and dependent variables. It is from categorizing, evaluating and selecting variables that the model for study will be developed.

Sample Sources

Newfoundland Department of Education

The Newfoundland Department of Education, during the 1992-1993 school year, responded to curriculum evaluation concerns by improving its high school course summative evaluations (that is, the year end public exams). Improvement meant a more accurate, and most important, more consistent summative evaluation. To provide a set of appropriate questions the Department of Education randomly sampled 77 schools throughout the province (84 teachers and 1771 physics students) to complete a physics question analysis. The sample was divided equally into 23 groups and each group then completed a test on one unit of Physics 3204. The Newfoundland Department of Education provided this study with the results of the item validation and augmented it with background information about the students and teachers involved in the testing. The database of student and school information, which this research further developed, was large and comprehensive.

The information initially provided represents important confounding variables that may affect MBL use, or its relationship to physics achievement. Included at the student level was demographic and academic information such as science and mathematics courses presently enrolled in and marks of any completed, student gender, and age. At the school level, data included pupil-teacher-ratio, years teaching experience, teacher certification level, total school enrolment, school type, and school region. Combined, this data set constituted a vast pool of information about physics students and their learning environment. It did not include, however, anything related to the availability of, or student use of, computer technology. The only possible method of gathering this pertinent information was through a well designed teacher survey.

Teacher Survey

The intent of this research was to investigate MBL and its effect on physics achievement. Confounding teacher and classroom variables related to MBL, therefore, were investigated and controlled. A survey was designed to gather information about teacher qualifications (e.g. academic background, computer aptitude). teacher attitudes towards computer use during instruction, and student physics class experiences. Since the teachers involved in the Department of Education's item analysis were volunteers. and willing participants, a high rate of return was anticipated. Eighty-four physics teachers were surveyed late in the 1992-1993 school year with 92% responding. The survey was designed to gather information pertaining to the sample student's classroom environment and experiences. the survey was divided into four sections

1. **Resources**: This section refers to the computer resources (both software and hardware), and expertise available to the students. In a short response format, teachers were asked to state the degree and extent of their computer experience; and to list the equipment available for student use. The answers would help determine how much students used computers. and, more specifically, how much MBL occurred during physics instruction.

2. **Extent of Computer Use**: In a multiple choice format, teachers were asked the extent to which students actually used the computer. and what they believed was the ideal frequency of student computer use during physics instruction. With the possibility of teachers not having any computer expertise and/or not knowing current computer educational uses, the questions, all following a similar format, were subdivided into six categories: 1. Demonstration Programs. 2. Drill-and-Practice,
3. Laboratory Simulation. 4. Tutorials. 5. Classroom Management. and,
6. Laboratory Tool (MBL). Each began with a brief definition. and example activities or software. then broke into two specific questions pertaining to

actual student use versus ideal student use (see sample survey question below)

6. Laboratory Tool. The use of computers. along with additional interfaces, to capture, store, analyze and display experimental data. Examples: Super Champ, Vernier.

> *A. Which best describes **your students' current frequency of use** of computers as a laboratory tool for physics instruction:*
>
> *B. Which best describes what you believe **the ideal frequency of your students' use** of computers as a laboratory tool for physics instruction should be:*

Answering the questions. teachers chose between six possibilities: (1) once a day. (2) once a week. (3) once a month, (4) 2 to 5 times a year, (5) once a year. and (6)-never.

If the actual student use scores were low. indicating little MBL affect on achievement. an obvious question would be why wasn't the computer utilized more often? A common teacher comment is that they are willing and enthusiastic to use MBL. however. they lack equipment and expertise. If this is true. then. although scores on "actual use" may be low; scores on "ideal student use" should be much higher. It was decided that "actual use" and "ideal use" question mirroring for all six categories of computer use may produce data that could defend this teacher response.

Computer use was divided into six categories because any academic benefit of MBL may be masked in the effect of a general student computer aptitude that would develop if a teacher often employs computer technology in many different classroom situations. In other words, achievement in Physics may be affected by MBL, or by Drill and Practice, etc., or, more generally, by a student computer aptitude which is the result of varied computer utilization during instruction. Perhaps the data may indicate that MBL will only influence achievement as a part of a student computer aptitude. It is important to delineate the relationship of MBL to achievement, and how it may be interconnected with other computer uses during instruction.

3. **Laboratory and Computer Use**: If teachers utilized the computer during laboratory classes, further details about student laboratory experiences were required to determine if MBL is an influencing factor. Teachers may have students engaged in MBL every laboratory; however, the students may only participate in these activities once every five weeks, perhaps for short time periods, and within large student groups. Under these

conditions you would expect MBL's effect on achievement levels to be minimal. Potentially, teachers may have utilized computer interfacing, and so students have experiences with it, however, experiences such as demonstrations or remediation limit students to observing. Any effect of MBL would be greatly reduced because of a lack of student control and hands-on interaction. In this section, in a check list format, teachers were asked pertinent details, such as time spent on laboratory activities, student group size, and the role of computer interfacing.

4. **General**: Student achievement has a complex relationship with numerous attributes of the classroom environment. The focus of this research, however, is the contribution of MBL activities and its relationship to achievement. When compared to other variables such as teacher qualifications or textbook selection or more importantly student physics ability, the effects of MBL may be very small. Furthermore, these variables may partially determine the amount of MBL and its effectiveness. For example; a particular textbook, or elective unit taught, may increase, or vary, student MBL experience. Conceivably, MBL activities may only become significant for students of teachers with little experience, because these teachers usually rely less on traditional methods. To explore these possibilities, data such as: teacher academic major; teacher academic

minor; years teaching experience; textbook used; course unit order; and optional unit completed were collected in a short response format that ended the survey.

The survey data, combined with information from the Newfoundland Department of Education, produced an extensive set of potentially influencing variables and of student outcomes. For clarity, this database can be organized into three categories (see table 3.1):

STUDENT FACTORS	CLASSROOM FACTORS	SCHOOL FACTORS
Gender	*Textbook Used*	*Month student wrote test*
Date of Birth	*Computer Interfaces Used*	*Urban/Rural*
Student Math Marks	*Rank of Computer Use*	*Type of School*
Student's Science Marks	*Order of Unit completion*	*Total School Enrollment*
Final Physics School Mark	*Teacher's Years Experience*	*School Region*
Final Physics Exam Mark	*Optional Unit completed*	*School District*
Student's present Math Courses	*Teacher's Computer Experience*	*No. of Computers available for science instruction*
Student's present science course(s)	*Extent of Computer Use for science instruction*	*School Pupil - Teacher Ratio*
Individual Question Responses	*Ideal Extent of Computer Use for science instruction*	*Software available for science instruction*
	Teacher's Certification Level	
	Teacher's Minor in University	
	Teacher's Major in University	
	Extent of Laboratory Use in Physics Instruction	
	Teacher's Experience Teaching Physics	

Table 3.1: Data set collected

These factors were the foundation from which this research would be based. Unfortunately, not all the data representing potential influences on physics achievement (although interesting) were studied. Only factors that arguably influenced the use of MBL, and influenced MBL's effect on achievement, were examined

Variable Selection

Student Factors

The major sources of student-based variables are the item analysis data and Newfoundland Department of Education statistics. Included were: gender, date of birth, all mathematics courses completed and marks received, all science courses completed and marks received, all science courses presently enrolled in, all mathematics courses presently enrolled in, item-by-item results of unit exam (results of each form), Physics 3204 school mark, Physics 3204 public exam mark, and final Physics 3204 mark. Upon first examination, it appears that there was a large database pertaining to student achievement in secondary school. For various reasons, unfortunately, much of this data was not useful for this research.

First, the item analysis achievement data was not based on a consistent measuring instrument. Of the 1771 students involved in the item analysis, no more than 123 wrote the same form. Each of the 23 forms had completely different questions derived from one of the six units in Physics 3204. In other words, each group of students, sorted by the 23 different forms of the item analysis, wrote unrelated evaluations. There was no effort to make the forms equal in content, difficulty level, or structure. Moreover, these evaluations were administered by the classroom teacher while students were still completing the course. There was no effort to ensure students had completed the same amount of the course before testing, therefore, differences in achievement may have been the result of what and how much physics was completed, rather than by any instructional method or other treatments. Any outcome based on the form results would merely indicate achievement on a particular test in a particular unit of study.

Another potentially interesting group of data was the completed science and mathematics marks, and courses presently enrolled in. At first glance these may indicate some predisposed aptitude towards science and mathematics, possibly a powerful determinant affecting physics achievement. Complicating this data, however, was the wide range of choice in science courses, and the three streams of mathematics curricula available to Newfoundland students. Some students, presently completing Physics 3204, did not have any other science course completed, while others had up to four done. Moreover, the sample of students tested was dispersed amongst all three mathematics streams (basic, academic, and advanced) which resulted in achievement data from six different mathematics courses. The academic background of students in the sample was very diverse, therefore, virtually incomparable. The only secondary course common to most members of the sample was Physics 2204, the course often considered a prerequisite to Physics 3204. Achievement data for Physics 2204 was used as a measure of pre-treatment physics ability and was a control variable (for student background) within the model. However, because of the way that this data was determined, it may have questionable validity and reliability.

For 2000 level courses in Newfoundland each group of students (based on the school they attended) was exposed to teacher-formulated evaluation. Teacher-based evaluation has traditionally been criticized (Crocker, 1989), since teachers may lack the time and expertise to produce valid, criterion referenced instruments which evaluate curriculum intended learner outcomes, and may not practice objective means of marking. It can be argued, however, that these tests do evaluate teacher intended learner outcomes, and so have a high measure of validity. Ideally, these two sets of outcomes coincide with each other, but based on local conditions, sometimes they may not. Student achievement on these evaluations are valid, however, in the sense that they are measures of what a student knows in comparison to what the teacher expected them to know. Since these expectations are founded in the physics subject matter, the Physics 2204 marks are evidence of pre-3204 physics ability, despite any mismatch with specific physics curriculum objectives.

Concerns about validity and reliability in 2000 level course achievement arise because it is the sole responsibility of individual schools, and are thereby subject to local conditions. Student evaluation in 3000 level courses (the second and final course of a subject) is assumed much more rigorous and dependable, since it is based on a common curriculum and final exam determined by Newfoundland's Department of Education. The guidelines stipulate that the final grade is a calculated average between a school-based mark, supplied by the classroom teacher, and final exam mark, supplied by the Department of Education (see figure 3.1). The school-supplied mark is intended to represent work completed throughout the course, such as unit tests, assignments, laboratories, and so on. The Department of Education mark represents student achievement on the summative exam (produced and administered by the Department) referred to as the public exam. In determining the overall student achievement, the Department of Education analyzes both school marks and public exam outcomes for significant differences. If any are

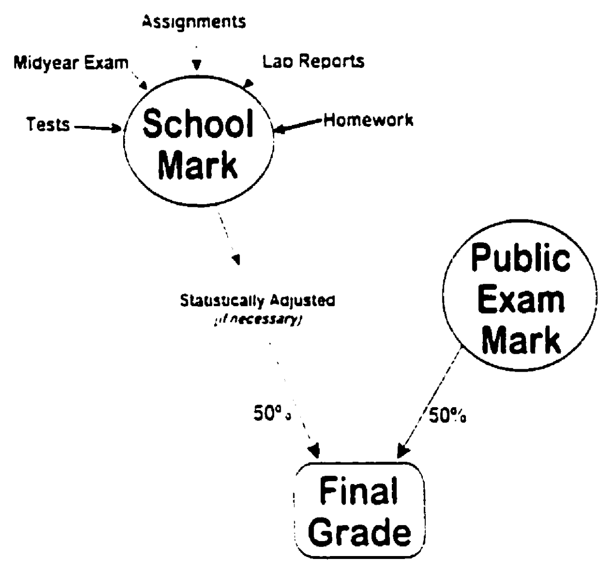


Figure 3.1: 3000 level course evaluation scheme

found, the school marks are statistically normalized before the average is calculated. Since all students in the sample were enroled in Physics 3204, they were required to complete, under similar conditions, the same summative evaluation. This evaluation is formulated and standardized by a group of curriculum experts utilizing a bank of questions that have high validity and reliability (note the item testing in Physics previously referred to), and are based on the course intended learner outcomes. Once written, the exam papers are marked by a team of experienced physics teachers (approximately six) in a controlled process where each teacher is assigned particular questions to mark and standards are checked on a continual basis. The exam results, therefore, are a good, objective measure of a student's Physics 3204 knowledge and were used as a dependent variable representing physics achievement.

The public exam, because of physical constraints such as time, materials, and diversity of student classroom experiences (every student representing every Newfoundland high school must write the public exams) can not, however, accurately measure all outcomes of the physics curriculum. Science processes such as experimenting, controlling variables, and extrapolation, for example, are difficult to include in a three-hour paper-and-pencil exam designed to evaluate ten months of physics study. It can be assumed that the level of achievement in student inquiry skills, attitudes towards science, and critical thinking skills (emphasized in the laboratory setting) would be better reflected in the school-based mark. This mark has a measure of validity because it is the result of many evaluation instruments which probably utilize various techniques such as laboratory reports, research papers, and quizzes. Combining these evaluations means the school-based mark represents a comprehensive, more diversified measure of student achievement. MBL's strong association with practical work may imply that any affect it has on student achievement would be most prominent in the school-based mark. It is often assumed, however, that the school-based marks lack rigor and validity since they are usually different than corresponding public exam marks. On the other hand, Crocker (1989) argued that the differences in value between school-based, and, public exam marks, which was also evident in this sample, may be the direct result of the differences in evaluation techniques and purposes. The school-based mark, with a stronger practical component, was also a dependent variable in this research representing student Physics 3204 achievement .

Classroom Factors

Classroom related data, obtained from the survey and the Newfoundland Department of Education, made up a diverse collection of variables, some of which may have a questionable relationship to MBL use and its affect on achievement. Only variables which could be connected to this relationship, therefore, were considered. For example, the teacher ranked purposes for MBL generated interesting data pertaining to teacher instructional uses of computer interfacing, however, it was not within the scope of this research to determine which application of MBL is the best. It should be established that MBL has an effect on achievement before delineating any particular requirements for its use. Data such as this was left for further study. All utilized classroom factors were teacher-related since they either depended on teacher qualification, or instructional attitudes and decisions made by the teacher. This information was a direct measure of the classroom environment in which students were taught physics, and so may have had a direct affect on student MBL use and physics achievement.

Teacher background variables, predictors of teaching ability, would have a profound effect on MBL use and student achievement. Teaching ability is a complex, difficult-to-measure quality which results from many contributing factors. In the absence of any direct measure, the research included variables such as teacher's microcomputer experience, teacher's educational background, teacher's certification level, and years teaching experience. This teacher background information may not equate to teacher ability, however, they are a contributing factors, and so their effect on MBL use and physics achievement was analyzed. For example; a teacher with little or no computer knowledge would most likely not utilize MBL activities, if he or she did, in all likelihood it would not be as effective. A more experienced teacher, with a background in physical science would presumably be more familiar with the subject matter and effective instructional methods. With a high probability of producing more knowledgeable physics students, the experienced teacher might have more time to explore and maximize new methods such as MBL. A positive attitude toward computer innovation is not limited to experienced, successful teachers. It may be an important contributor to the success of less experienced teachers. Teacher experience, attitude and background, indicating increased teaching ability, may, therefore, have a direct affect on the use and effectiveness of MBL.

The myriad of teaching philosophies, methods, materials and so on, that are possible, each with their own set of advantages and disadvantages, makes the relationship between the classroom environment and achievement complex and difficult to delineate. If microcomputer based laboratories however have any influence on achievement, then teachers must establish a learning environment that is conducive for its use. Furthermore, the data may indicate a relationship between teacher background, learning environment, and level of MBL use. Perhaps some veteran teachers realize the potential benefits of MBL, but see them as no better than present methodologies. It is possible that teachers, upon critical examination, determine that microcomputer based laboratories do not significantly improve the laboratory experience, which in itself has little effect on student achievement. These possibilities may be caused by predisposed negative opinions about the role of the laboratory and computer use within the curriculum. In an attempt to study these, this research included such variables as: extent of laboratory use in physics instruction, extent of computer use for science instruction, and teacher attitude toward computer use for science instruction. These may directly affect achievement, or be a part of any MBL use-achievement relationship.

School Factors

Major differences in Newfoundland's education system have traditionally been attributed to the province's socio-economic situation and the rural-urban split which divides Newfoundland citizens into two groups. One group, urban residents, are, on average, well educated, middle class, and live in the centers of commerce. Rural Newfoundland's livelihood, depending mainly on fishing, forestry or mining, has fluctuated greatly. The result is people living in very small isolated communities, have lower average annual incomes, a lower resource base, and a lower average education level than people living in urban centers. This diversity in background and environment results in many differences in the schooling provided to each group. For example, rural schools generally have smaller enrolments, fewer financial resources (from total budget allocations, cafeteria sales, etc.) and a more limited curriculum, all of which may negatively influence MBL use and physics achievement. Teachers working in rural schools often contend, however, they enjoy a greater parental input (such as direct, community-based financial assistance and greater teacher-parent cooperation) and lower pupil-teacher ratio. These may counteract any negatives associated with rural schooling.

The specific differences in schooling provided to rural v.s. urban students are complex, and for the purposes of this research, need not be delineated. In the past, however, rural schools were considered disadvantaged with regards to curriculum resources and the lower average student socio-economic background. If microcomputer based laboratories in rural schools have little or no affect on physics achievement, perhaps a lack of resources is a problem. Rural teachers may be willing and open minded, but have no equipment to employ the laboratory techniques. More research would be required to determine why. Furthermore, if student socio-economic background, predicted by student and school location, is a powerful confounding variable, then it may mask any affect MBL may have on achievement. Compensating for these deficiencies, rural teachers, with smaller class sizes, may offer more individualized instruction, thereby improving expected achievement. For these reasons this study included the school variables rural/urban, and school enrolment.

Summary

The primary question: "Does MBL use have an affect on student physics achievement?" was answered by determining the effect of the treatment (MBL use) on the physics final exam mark and physics final school mark while controlling for potential interfering variables. The variables were grouped into three categories: 1. student factors; 2. classroom factors; and 3. school factors (see table 3.2).

STUDENT FACTORS	CLASSROOM FACTORS	SCHOOL FACTORS
Pre-treatment Physics Ability	*Teacher's Certification Level*	*Urban/Rural School*
	Teacher's Years Experience	*Total School Enrollment*
	Teacher's Academic Background	
	Teacher's Microcomputer Experience	
	Extent of Laboratory Use in Physics Instruction	
	Extent of Computer Use for Science Instruction	
	Teacher Computer Use Attitude	

Table 3.2: Variables researched

If MBL use is a significant indicator of achievement then it is important, if we want to improve achievement, to determine what variables affect the level of MBL use. This study investigated teacher's academic background, teacher's years experience, extent of laboratory use, teacher's computer attitudes, teacher's computer ability, school location, and so on, to determine whether these variables affect students' exposure to MBL methods. Understanding which variables are fundamental determiners of MBL use may assist education leaders to maximize MBL and, therefore, increase physics achievement. If, on the other hand, analysis indicates MBL use has no effect on physics achievement then, this study will attempt to explain these results by further exploring student classroom experiences and teacher attitudes towards computer technology.

One reason why MBL use may have little effect on physics achievement is the distinct possibility of low student MBL use. In the past, a perceived lack of student MBL activities was attributed to many causes, most notably, the lack of equipment (associated with poor funding) and the lack of teacher expertise. If this research can determine problems associated with MBL use, steps may be taken such as, increase funding or teacher inservice to encourage MBL use. Removing other potential barriers such as negative teacher attitudes about the instructional use of the computer, and thereby increasing MBL use may be more problematic. By investigating the MBL use variable, this research attempted to determine if it is the primary reason for the lack of a MBL use-physics achievement relationship, and if so, delineate the possible causes for it. Determining this would allow Newfoundland's school leaders to develop responses and attempt to correct the situation. See figure 3.2 for the complete model analysis.

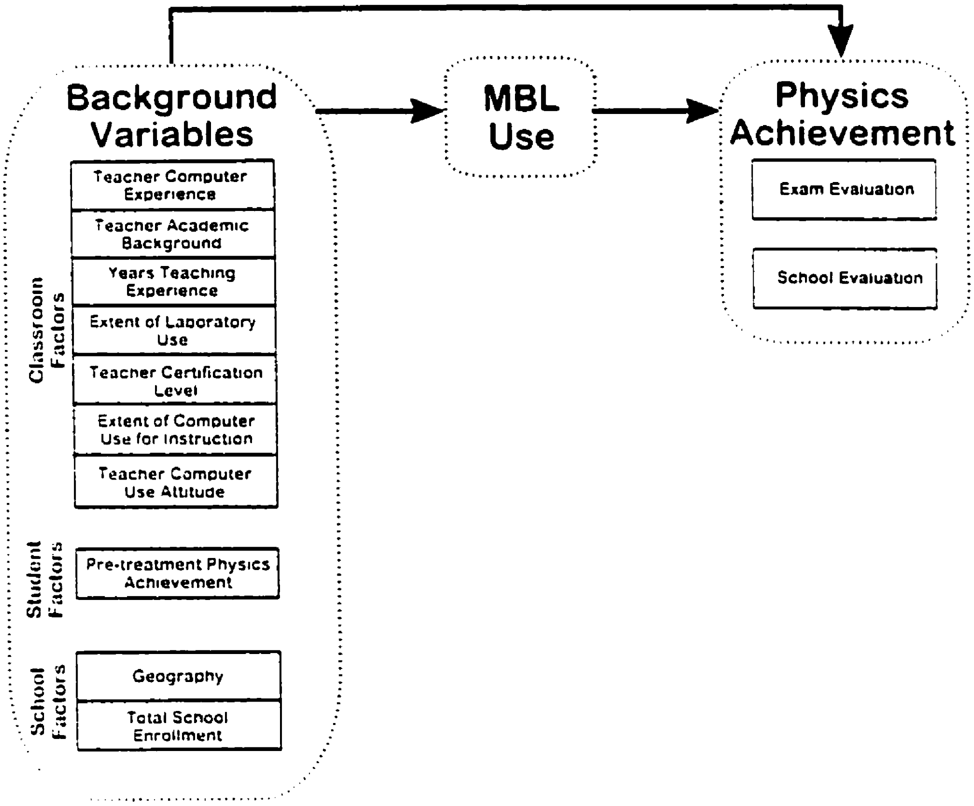


Figure 3.2: *Analysis model.*

CHAPTER FOUR

RESULTS AND ANALYSIS

Examining the Data

Introduction

Compiling the relevant information, representing 1688 students and 85 teachers, produced a data set with two frames of reference, student referenced data (where teacher, classroom, and school related data is repeated for each student) and teacher referenced data (where student related data is aggregated). The unit of analysis for this research is at the teacher level, that is, the study investigated the effects of teacher-determined factors (at the classroom level), such as teacher academic background, school location, teacher computer experience, etc., on student MBL use and student physics achievement. Furthermore, this research controlled for these factors and investigated any relationship between MBL use and physics achievement. Although hierarchal linear modeling may have presented a more rigorous analysis without a loss of levels of significance or degrees of freedom associated with a decreased sample size, aggregating the large sample of students was considered acceptable for this exploratory research. The data set, therefore, was aggregated and analyzed at the teacher level using the average student public mark and the average student school mark as dependent variables, indicating the student achievement level of a particular teacher. The aggregate data was further prepared for statistical analysis by numerical coding of raw scores and item analysis to create the teacher attitude toward computer use variable, and other computer use variable.

Data Encoding

Coding raw data began with obvious numerical representations for text input. For example: school location, reported as "rural" and "urban", was recoded into 2 and 1 respectively. Likewise, the variables teacher academic background, school type, teacher computer experience, and teacher years of microcomputer experience were numerically coded. The variable student laboratory time, which indicates the average time per unit spent on laboratory activities, was transformed from a six-level ordinal variable (½ hour, 1 hour, 1½ hour, 2 hours, 3 hours, and >3 hours) into a dichotomous variable (sufficient time and insufficient time). Any response of 2 hours or lower was recoded insufficient, while 3 hours or higher was recoded sufficient. This was based on the Newfoundland Department of Education curriculum guidelines for Physics 3204 that suggest teachers complete a minimum of 12 core student laboratories. Based on the suggested time required for each, a minimum of 3 hours per unit would be reasonable, and therefore, was judged sufficient.

The multiple choice responses to teacher questions pertaining to current and ideal instructional computer use were also recoded into dichotomous variables as "users" and "nonusers". It is not the intention of this research to decipher a relationship between the level of MBL use and physics achievement; this will be left for further study. Instead, this exploratory research examined the relationship of student MBL use (defined as "user" or "nonuser") and their physics achievement. To categorize microcomputer based laboratories use, the six possible responses (based on the amount of instructional time) were recoded. If teachers choose one of the possible answers: (1)-once a day, (2)-once a week, (3)-once a month, and, (4)-2 to 5 times a year, they were considered users of, or, in the case of "ideal use" questions, in favour of, a particular instructional method. This grouping is considered reasonable since "once a day", "once a week", and, "once a month" constitute a considerable level of instructional computer use. The "2 to 5 times a year" response may appear low to be considered a "user", however, any teacher who chose this option also chose it, or more frequent use options, in other computer use categories. It is reasonable, therefore, to consider these teachers knowledgeable computer users who integrate computer technology into several different aspects of classroom instruction. There is a good probability that when these teachers employ MBL, 2 to 5 times a year, the student experiences are extensive, and therefore, will be recoded as users. The selections of (5)-once a year and (6)-never were recoded into "nonuser" since it is very unlikely that this amount of computer-related instruction, over a ten month period, would have any measurable affect on physics ability. This recoding is considered reasonable, since upon examination of responses to instructional computer use, and ideal instructional computer use items, it is evident that a dichotomy exists. That is, most teachers, whether actual or ideal computer use, selected responses 1 (once a day) through 3 (once a month), or 6 (never). A low percentage of teachers chose moderate options such as 4 (2 to 5 times a year) or 5 (once a year). For example; for ideal use, on average, 12.78% selected the middle choices "2 to 5 times a year" and "once a year" (See table 4.1).

Response	Recoded	Average Actual Use Frequency		Average Ideal Use Frequency	
(1)-once a day	User	3.24%	35.98%	7.44%	92.79%
(2)-once a week		6.46%		43.50%	
(3)-once a month		11.31%		32.09%	
(4)-2 to 5 times a year		14.98%		9.76%	
(5)-once a year	Nonuser	8.55%	64.02%	3.02%	7.21%
(6)-never		55.47%		4.19%	

Table 4.1: Frequency of responses on items related to computer instructional use.

Item Analysis

Teacher attitude towards instructional innovation may be a potent factor which fundamentally affects the success or failure of the innovation. In this research, teacher attitude was measured by two separate variables ("teacher computer use attitude" and "current instructional uses w/o MBL"), each a composite of results from several items.

"Teacher computer use attitude" was produced from survey items associated with teachers' perceptions about the ideal use of the computer as an instructional aid. Generally, if teachers responded that a high use of computer technology is "ideal use" then these teachers were portraying a very positive attitude about the role of the computer during physics instruction. On the other hand, low "ideal use" scores implied a negative attitude. The variable was constructed by the addition of responses from "ideal computer use" items (see Table 4.2). As reported previously, ideal computer use items, originally Likert scale data, were recoded as 1 - user or 2 - nonuser, therefore, the range of the teacher computer use attitude variable was from 6 - a very positive attitude to 12 - a very negative attitude. Teacher responses with incomplete ideal use data were considered missing and dropped from the item analysis. Nonetheless, the ideal use data had an acceptable alpha reliability of 0.7668. The item results indicated teachers display a very positive attitude towards instructional computer use (see chart 4.1).

Item	**Question** - responses recoded to 1 (positive attitude) and 2 (negative attitude)
Q8	Which best describes what you believe the ideal frequency of your use of demonstration programs for physics instruction should be:
Q10	Which best describes what you believe the ideal frequency of your students' use of drill-and-practice programs for physics instruction should be:
Q12	Which best describes what you believe the ideal frequency of your students' use of laboratory simulation programs for physics instruction should be:
Q14	Which best describes what you believe the ideal frequency of your students' use of tutorial programs for physics instruction should be:
Q16	Which best describes what you believe the ideal frequency of your use of classroom management programs for physics instruction should be:
Q18	Which best describes what you believe the ideal frequency of your students' use of computers as a laboratory tool for physics instruction should be:

Cronbach alpha reliability = 0.7668

Mean	Median	Mode	Std. Deviation	Coding
6.45	6	6	1.14	ordinal variable, range from 6 (positive attitude) to 12 (negative attitude)

Table 4.2: Computer use attitude variable.

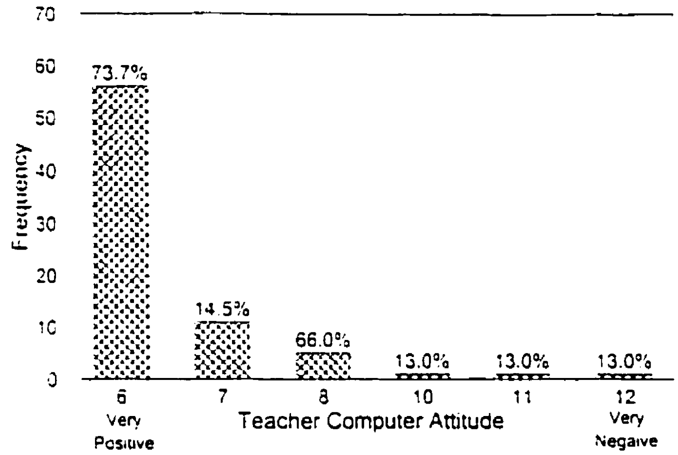


Chart 4.1 Teacher Computer Attitude

The "Current instructional uses w/o MBL" variable is a measure of present computer instructional use excluding MBL. It was constructed by the addition of responses from "computer use" items (excluding MBL use a total of five items, see Table 4.3). Similar to the computer use attitude analysis, originally Likert scale data, were recoded as 1 - users or 2 - nonusers, therefore, the range of the teacher computer use (w/o MBL) variable was from 5 - high use to 10 - no use. Teacher responses with incomplete computer use data were considered missing and dropped from the item analysis. The remaining items had an acceptable alpha reliability of 0.7317.

Besides indicating teacher attitude towards computer use, this variable offers insight into teacher computer skill level and openness to instructional innovation.

At the time of the survey's completion, any physics curriculum-technology integration would have been at the discretion of individual teachers, since few Department of Education or School Board directives in this area existed. Teachers who responded as users of computer technology during instruction,

Item	**Question** - responses recoded to 1 (user) and 2 (nonuser)
Q7	Which best describes your current frequency of use of demonstration programs for physics instruction:
Q9	Which best describes your students' current frequency of use of drill-and-practice programs for physics instruction:
Q11	Which best describes your students' current frequency of use of laboratory simulation programs for physics instruction:
Q13	Which best describes your students' current frequency of use of tutorial programs for physics instruction:
Q15	Which best describes your current frequency of use of classroom management programs for physics instruction:

Cronbach alpha reliability = 0.7317

Mean	Median	Mode	Std. Deviation	Coding
8.44	9	9	1.44	ordinal variable: range from 5 (very high use) to 10 (no use)

Table 4.3: Computer use for science instruction (excluding MBL).

therefore, showed a willingness to try new methods and possibly improve their teaching, which implied that they possessed the necessary skills to choose the computer as the instructional aide. Microcomputer based laboratory use is excluded from the variable. since other instructional uses may be a powerful indicator of MBL use and this association will be examined in this research. In other words, teachers who are already familiar with instructional computer use, and have the available resources may be more inclined to try MBL. With developed computer skills, these teachers should produce more effective student-MBL sessions, thereby improving student physics achievement. Results indicated that teachers choose "nonuser" , i.e., once a year or never, to many of the "current use" items (see chart 4.2) which indicated an overall low level of computer integration. For example, 24.0% of teachers sampled were complete nonusers, while another 34.7% were computer users in only one area of instruction. It appears that teachers have positive attitudes towards the incorporation of computer technology into classroom instruction (see chart 4.1), however, based on responses to current use items (see chart 4.2) other extraneous factors are limiting their ability to do so.

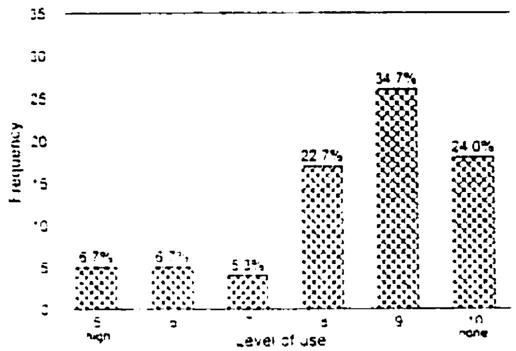


Chart 4.2: Teacher computer use (w/o MBL)

Data Gathered and Survey Results

The Students

As stated previously, the Physics 3204 student sample analyzed by this research was selected by the Newfoundland Department of Education. It was selected with the intent of producing an academically diverse sample that had approximately equal gender and geographic representation. The sample chosen was comprised of 1688 students taught by 84 teachers (representing 83 schools). The students were of 55.2% males and 44.6% females with the majority (91.1%) between the ages of 17 and 16. The students' geographic location was split almost equally between rural and urban Newfoundland (rural - 49.9%, urban - 50.1%). Since each school represented in the sample did not contribute equal number of students, the sample schools' geographic locations are divided 60.0% rural, 38.8% urban.

The students' Physics 3204 public exam achievement, consistent with province-wide statistics, was distributed normally around a mean of 58.02 (see table 4.4 and charts 4.3 and 4.4).

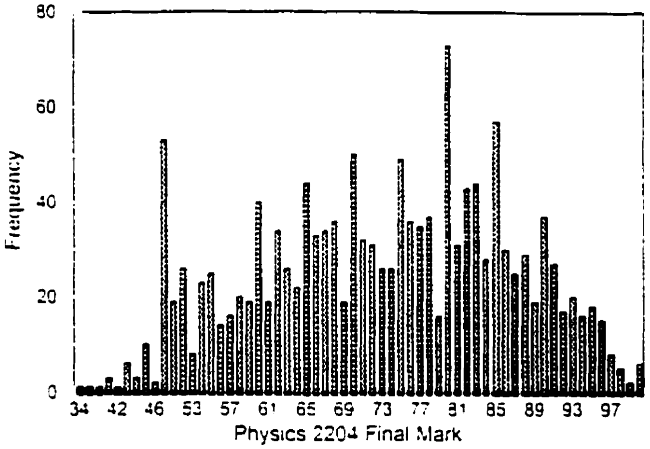


Chart 4.3: Distribution of Student Physics 2204 Marks

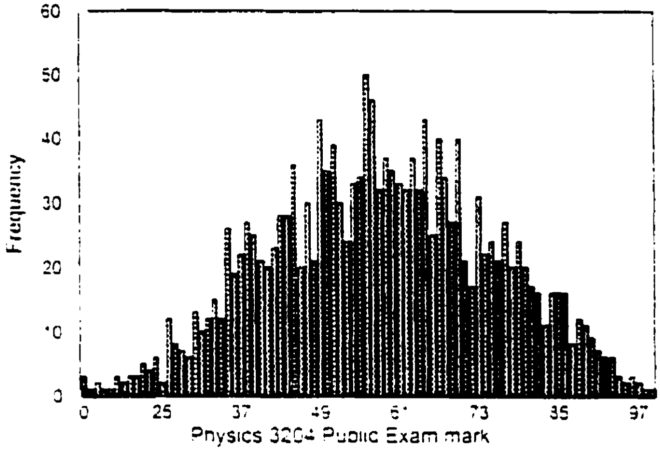


Chart 4.4: Distribution of Student Physics 3204 Public Exam Marks

	Mean	Median	Mode	Std. Deviation	Coding
Physics 3204 public exam mark	58.02	58.00	56	16.85	actual values (range from 0 to 100)
Physics 2204 mark	73.11	74.50	80	13.29	actual values (range from 0 to 100)

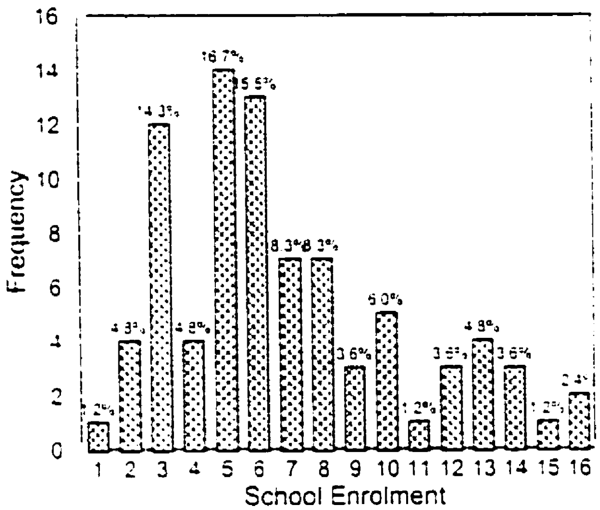
Table 4.4: Student Physics achievement

The Teachers and Schools

Data gathered pertaining to the teachers and their schools, provided an interesting snap-shot of Newfoundland's typical physics learning environment (see table 4.5 and 4.6). Of the physics teachers within this sample; 45.2% have a level six certification (meaning they have completed a minimum of 60 university credits); 90.8% have more than one year of microcomputer experience; and; 52.6% of them studied physical science at the post secondary level. Their teaching and teaching physics experience, however, is much more diversified, with 66.2% having more than 10 years of teaching experience, while only 48.7% having similar experience in physics teaching (see Table 4.5). The school and classroom environment of the research sample was, in many respects, typical for the majority of Newfoundland teachers. Within the sample of schools: 60.7% are in rural areas (39.3% urban); 31.8% have a student population between 251 and 350 (see chart 4.5); and; 52.4% have a pupil-teacher ratio between 14.1 to 19.5 (see chart 4.6). The types of schools within the sample are almost equally divided between all grade (23.8%), 7-12 (42.9%) and high (33.3%). It was assumed that schools with greater than 250 students (75.2 %) would have the necessary budget to acquire the adequate laboratory facilities. Moreover, pupil-teacher ratios below 20 (78.6%) would seem to be conducive for practical, and technology assisted, physics instruction.

Variable	Value	Per Cent
Teacher Certification Level	4	3.6%
	5	23.8%
	6	45.2%
	7	21.4%
Teacher Microcomputer Experience mean: 2.68 median: 3 mode: 2 Std. Dev: 0.91	0-1 year	9.1%
	1-4 years	34.8%
	5-9 years	34.8%
	10-20 years	21.2%
Teaching Experience mean: 13.68 median: 14.5 mode: 20 Std. Dev: 8.01	1-4 years	18.9%
	5-9 years	14.9%
	10-14 years	16.2%
	15-20 years	32.4%
	21-24 years	8.1%
	25-30 years	9.5%
Physics Teaching Experience mean: 9.96 median: 9 mode: 2 Std. Dev: 7.52	1-4 years	35.1%
	5-9 years	16.2%
	10-14 years	17.6%
	15-20 years	24.3%
	25-30 years	6.8%

Table 4.5: Teacher background data



Legend	
1	50 to 100
2	100 to 150
3	150 to 200
4	201 to 250
5	251 to 300
6	301 to 350
7	351 to 400
8	401 to 450
9	451 to 500
10	501 to 550
11	551 to 600
12	601 to 650
13	651 to 700
14	701 to 750
15	801 to 850
16	>850

Chart 4.5: Distribution of School Enrolment

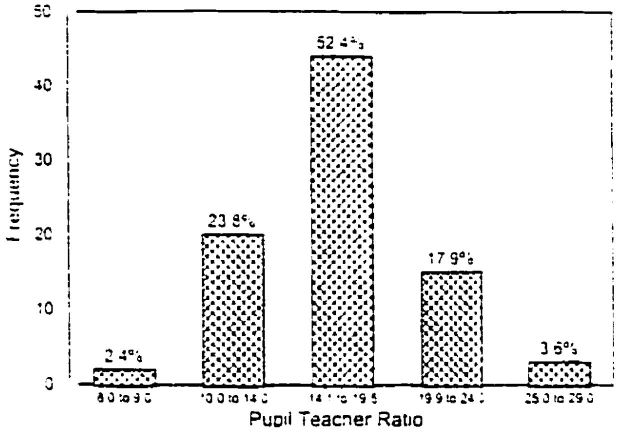


Chart 4.6: Distribution of Pupil Teacher Ratio

These assumptions, however, are not supported by the survey results pertaining to physics instruction. Surprisingly, 54.1% of the teachers who responded offered "insufficient" (based on recoding of data) student lab time per unit of instruction. Obviously the majority of teachers were not completing the minimum, required laboratory exercises, therefore, due to the level of treatment, any effect of student practical experience on physics achievement would be diminished.

	Mean	Median	Mode	Std. Deviation	Coding
pupil teacher ratio	16.71	16.13	$16.18^{(a)}$	4.01	actual values (range from 8.44 to 28.74)
school type	-	-	-	0.75	1 = K - 12 2 = 7 - 12 3 = 10 - 12
lab time	4.3	4	4	1.3	1 = ½ hour 4 = 2 hours 2 = 1 hour 5 = 3 hours 3 = 1½ hour 6 = > 3 hours
school location	-	-	-	0.49	1 = urban 2 = rural
school enrolment	385.58	321.5	546	229.62	actual values (range from 69 to 1370)

Table 4.6: School-classroom background statistics (a) multiple modes exist. The smallest value is shown

Current instructional computer use results (see chart 4.7) indicated the majority of teachers within the sample presently use technology in very limited roles. MBL use and classroom management (i.e., spreadsheets for marks, wordprocessors for test construction, etc.) were the only instructional uses in which the majority of teachers were users (55.3% and 69.3% respectively). Overall, current computer instructional use was not widespread; however, most of the teacher's in the sample believe that high computer use is the ideal method of instruction (see chart 4.7). It appears that a vast majority of teachers believe that computer technology should be integrated throughout the physics curriculum. The statistics indicated a contradiction between a teacher's actual methods of instruction and what they believe those methods should be. It may be very difficult to delineate why, with such a positive teacher attitude, computer technology is underutilized. This research attempted, however, to determine some of the intervening factors.

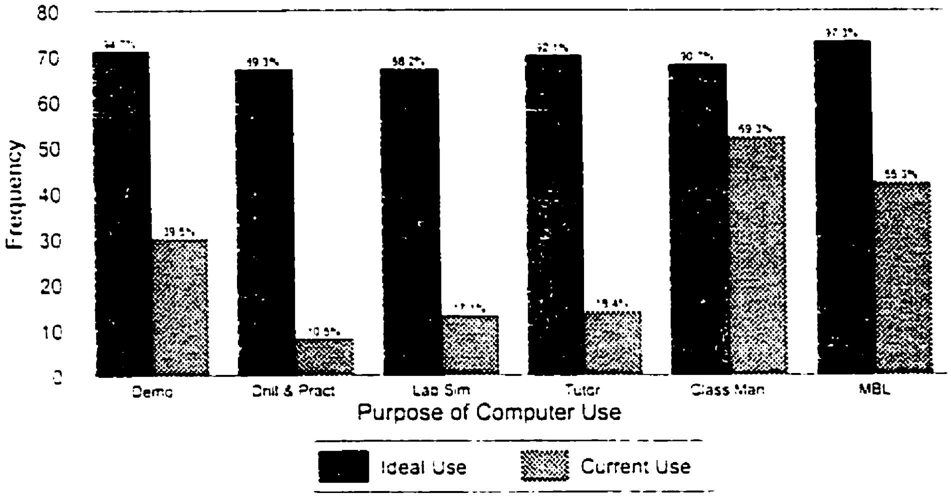


Chart 4.7: Distribution of Computer Use

Data Analysis

To explore the research questions posed, four separate multiple regression analyses were performed on each of three dependent variables (public exam achievement, school-based achievement, and MBL use). For each achievement dependent variable, the analyses included the treatment variable (MBL use), and a control for student background and pre-treatment ability (Physics 2204 achievement). The achievement dependent variables were then analyzed with each one of the three groups of potentially associated independent variables, i.e., with either the group of classroom variables, teacher variables, or school variables. Once completed, a fourth multiple regression was performed which included what the previous analysis revealed to be the "best" predictors of variance in the independent variable (i.e., an attempt to produce the most descriptive model). The choice of "best" regression model was based on the three earlier analyses and the relevant literature. The method of analyzing the association of classroom (teacher and school) variables with the achievement dependent variables, then producing the most descriptive model was repeated on the third dependent variable MBL use.

The multiple regression method of statistical analysis was chosen based on Kerlinger and Pedhazur's (1973) stated advantages of multiple regression over other statistical methods:

> *"...multiple regression is often the best method of analysis of nonexperimental data..multiple regression analysis is suited to almost any nonexperimental research in which there are several independent variables and one dependent variable (or one dependent variable at a time). No matter what the scales of measurement or what the kind of variable, useful analysis can be done and interpretations made." (p. 445)*

Research, like this study, involving different types of dependent and independent variables, therefore, demands multiple regression rather than ANOVA analysis. Furthermore, Pedhazur (1997) comments that multiple regression and ANOVA are equivalent when including categorical variables, however, with the inclusion of both categorical and continuous variables multiple regression is superior. Pedhazur states:

> *"The most important reason for preferring MR to ANOVA is that it is a more comprehensive and general approach on the conceptual as well as the analytic level. On the conceptual level, all variables, be they categorical or continuous, are viewed from the same frame of reference: information available when attempting to explain or predict a dependent variable. On the analytical level, too, different types of variables (i.e.. categorical and continuous) can be dealt with in MR." (Pedhazur, 1997, p.405)*

Pedhazur (1997) does warn, however, that results of multiple regression calculations involving categorical dependent variables require careful analysis as to avoid incorrect conclusions. Mindful of Pedhazur's (1997) concerns and based on personal conversations with Mr. Jeff Bulcock (See Appendix B), the mode of analysis chosen for this study was multiple regression.

Research Question 1: Factors Affecting Public Exam Achievement

	average public exam mark	school location	school enrolment	current MBL use	average Physics 2204 mark
average public exam mark	1.000				
school location	-0.304**	1.000			
school enrolment	0.288**	-0.527***	1.000		
current MBL use	-0.086	-0.018	-0.035	1.000	
average Physics 2204 mark	0.583***	-0.038	-0.026	0.202	1.000
Mean	58.0284	1.5821	398.7015	1.4179	72.5610
Standard Deviation	8.9740	0.4969	237.6527	0.4969	7.2177

Note: * $P < 0.05$, **$P < 0.01$, ***$P < 0.001$

Table 4.7: Correlations between Average Public Exam Mark and school-related background variables

Is MBL use associated with student achievement on the Physics 3204 Public Exam? Table 4.7 shows the Pearson correlations between school-related factors, MBL use, Physics 2204 mark and the average public exam mark. The results indicate that significant correlations exist between school location and average public exam mark (-0.304, $p < 0.01$ indicating urban schools have higher average public exam marks); school enrolment and average public exam mark (0.288, $p < 0.01$ indicating larger schools produce higher average public exam marks); school enrolment and school location (-0.527, $p < 0.001$ indicating that urban schools tend to be larger schools); and; average Physics 2204 mark and average public exam mark (0.583, $p < 0.001$ indicating that teachers with a high average Physics 2204 mark tend to have a high Physics 3204 mark).

Table 4.8 shows the results of the regression analysis performed on the average public exam mark using school-related background variables. The regression model was significant at the $p < 0.001$ level and explained 49.4% of the variance in the average public exam mark. Two variables, MBL use and average Physics 2204 mark, were significantly related to the average public exam mark. The beta weight of current MBL use (-0.208) indicates that teachers who were users of MBL methods were more likely to have higher average public exam marks. As expected, the beta weight of average Physics 2204 mark (0.623) was high and significant. It seems very logical that teachers who produce students with high

Physics 2204 marks will produce similar results in Physics 3204 achievement. Student background, student ability, school resources, teacher background, and teaching methods are unlikely to significantly change from one year to the next, therefore, the variables that produced a particular Physics 2204 achievement will have a similar affect on Physics 3204 achievement. The other school-related background variables did not reveal any significant effect on the regression model.

Dependent Variable: ***Average Public Exam Mark***					
Independent Variable	B	SE B	Beta	T	Sig T
school location	-3.191	1.925	-0.177	-1.658	0.102
school enrolment	7.682x10^{-3}	0.004	0.203	1.909	0.061
current MBL use	-3.755	1.668	-0.208	-2.251	0.028
average Physics 2204 mark	0.775	0.115	0.623	6.746	0.000
Multiple R	0.703		F value	15.108	
R Square	0.494		Sig. of F	0.000	
Standard Error	6.5888				

Table 4.8: Multiple regression analysis results for school-related background variables on Average Public Exam Mark

Table 4.9 shows the Pearson correlations between teacher-background factors, MBL use, Physics 2204 mark and the average public exam mark. The results indicate that many significant correlations exist between teacher-background variables. Noteworthy is the correlation between average public exam mark and teacher's major (-0.248, $p < 0.05$). The negative coefficient implies that teachers who are physical science majors are more likely to have high average public exam marks. This relationship, however, did not have a significant effect within the regression analysis.

Table 4.10 shows the results of the regression analysis performed on the average public exam mark using teacher-background variables. The regression model was significant at the $p < 0.001$ level and explained 44.1% of the variance in the average public exam mark. Only one variable, the average Physics 2204 mark, was significantly related to the public exam mark. As expected, the beta weight of average Physics 2204 mark (0.622) was high and significant.

	average public exam mark	years teacher micro experience	teacher's major	years teaching experience	teacher certification	current MBL use	average Physics 2204 mark
average public exam mark	1.000						
years teacher micro experience	0.195	1.000					
teacher's major	-0.248*	-0.124	1.000				
years teaching experience	-0.027	-0.229*	-0.229*	1.000			
teacher certification	0.086	0.268*	-0.143	0.116	1.000		
current MBL use	-0.092	-0.442***	0.214*	0.270*	0.098	1.000	
average Physics 2204 mark	0.536***	-0.200	-0.020	0.071	-0.177	0.221*	1.000
Mean	58.4364	2.6935	1.4516	13.8226	5.4677	1.4194	72.9608
Standard Deviation	8.9102	0.8979	0.5017	7.9970	1.6268	0.4975	7.0172

Note: * $P < 0.05$, **$P < 0.01$, ***$P < 0.001$

Table 4.9: Correlations between Average Public Exam Mark and teacher-background variables

Dependent Variable: *Average Public Exam Mark*

Independent Variable	B	SE B	Beta	T	Sig T
years teacher micro experience	2.057	1.209	0.207	1.702	0.094
teacher's major	-3.248	1.957	-0.183	-1.660	0.103
years teaching experience	$-6.139\text{x}10^{-2}$	0.124	-0.055	-0.493	0.624
teacher certification	0.716	0.615	0.131	1.165	0.249
current MBL use	-1.721	2.230	-0.096	-0.772	0.444
average physics 2204 mark	0.790	0.135	0.622	5.854	0.000

Multiple R	0.664	F value	7.239
R Square	0.441	Sig. of F	0.000
Standard Error	7.0142		

Table 4.10: Multiple regression analysis results for teacher-background variables on Average Public Exam Mark

Table 4.11 shows the Pearson correlations between classroom-related factors, MBL use, Physics 2204 mark and the average public exam mark. The results indicate that several significant correlations exist between classroom-related variables, however, only the average Physics 2204 mark was significantly correlated with the average public exam mark. It appears that classroom variables such as student lab time, other instructional computer use and teacher attitude toward computer technology have little effect on the public exam outcomes. This statement is further strengthened by the regression analysis results.

Table 4.12 shows the results of the multiple regression analysis performed on the average public exam mark using classroom-related background variables. The regression model was significant at the $p < 0.001$ level and explained 43.1% of the variance in the average public exam mark. Once again only the average Physics 2204 mark variable was significantly related to the public exam mark.

Dependent Variable: ***Average Public Exam***					
Independent Variable	B	SE B	Beta	T	Sig T
average Physics 2204 mark	0.789	0.126	0.641	6.240	0.000
student lab time	-2.816	1.837	-0.162	-1.533	0.131
current instruct uses (w/o MBL)	-0.296	0.786	-0.045	-0.377	0.708
current MBL use	-2.052	2.073	-0.116	-0.990	0.326
teacher computer use attitude	0.545	0.759	0.075	0.718	0.476
Multiple R	0.657		F value	8.803	
R Square	0.431		Sig. of F	0.000	
Standard Error	6.8439				

Table 4.12: Multiple regression analysis results for classroom-related background variables on Average Public Exam Mark

	average public exam mark	average Physics 2204 mark	student lab time	current instruct uses (w/o MBL)	current MBL use	teacher computer use attitude
average public exam mark	1.000					
average Physics 2204 mark	0.610***	1.000				
student lab time	-0.149	0.077	1.000			
current instruct uses (w/o MBL)	-0.076	0.086	0.315**	1.000		
current MBL use	-0.031	0.226*	0.278*	0.481***	1.000	
teacher computer use attitude	0.125	0.151	0.143	0.268*	0.100	1.000
Mean	58.4660	72.6047	1.5469	8.4531	1.3906	6.5313
Standard Deviation	8.7089	7.0767	0.5017	1.3205	0.4917	1.1948

Note: * $P < 0.05$, **$P < 0.01$, ***$P < 0.001$

Table 4.11: Correlations between Average Public Exam Mark and classroom-related background variables

Determining the variables to include in the final, most descriptive multiple regression model is very difficult for the dependent variable average public exam mark. Based on the three analysis completed, only average Physics 2204 mark, in other words, how students achieved in the past, has been a significant factor with all three groups of variables. The only other significant factor was MBL use when it was regressed with school-related factors. The final multiple regression for this independent variable, therefore, must include MBL use and average Physics 2204 mark. The other variables for this model were selected because they were the most significant (although not meeting the $p < 0.05$ level) and they were reasonable, potentially influential variables. Table 4.14 shows the Pearson correlations between background variables, MBL use, Physics 2204 mark and the average public exam mark. The results indicate that several significant correlations exist between background variables. In particular, a teacher's microcomputer experience appears to be a powerful predictor, since it significantly correlates with average public exam mark, teacher certification, school enrolment, and MBL use.

Table 4.13 shows the results of the multiple regression analysis performed on the average public exam mark using background variables. The regression model was significant at the $p < 0.001$ level and explained 55.7% of the variance in the average public exam mark. Two variables, years teacher microcomputer experience and average Physics 2204 mark, were significantly related to the public exam mark. The beta weight of years teacher microcomputer experience (0.230) indicates that teachers who have more microcomputer experience were more likely to have higher average public exam marks. The highly correlated average Physics 2204 mark had a beta weight of (0.687) which seems to verify that students who previously succeeded in physics will continue to do so. The other background variables, including MBL use, did not reveal any significant effect on the regression model.

Dependent Variable: ***Average Public Exam Mark***

Independent Variable	B	SE B	Beta	T	Sig T
years teacher micro experience	0.507	0.244	0.230	2.076	0.043
teacher certification	0.589	0.496	0.118	1.189	0.240
school enrolment	0.006	0.004	0.173	1.673	0.100
student lab time	0.307	0.641	0.047	0.480	0.633
current MBL use	-1.707	1.962	-0.095	-0.870	0.388
average Physics 2204 mark	0.846	0.114	0.687	7.404	0.000
Multiple R	0.747		F value	11.540	
R Square	0.557		Sig. of F	0.000	
Standard Error	6.201				

Table 4.13: Multiple regression between Average Public Exam Mark and background variables

	average public exam mark	years teacher micro experience	teacher certification	school enrolment	student lab time	current MBL use	average Physics 2204 mark
average public exam mark	1.000						
years teacher micro experience	0.271*	1.000					
teacher certification	0.177	0.245*	1.000				
school enrolment	0.284*	0.392***	0.338**	1.000			
student lab time	0.052	0.164	0.074	0.151	1.000		
current MBL use	-0.031	-0.394***	0.126	0.008	-0.341**	1.000	
average Physics 2204 mark	0.611***	-0.174	-0.068	-0.036	-0.144	0.225*	1.000
Mean	58.469	5.685	5.371	403.855	4.274	1.403	72.632
Standard Deviation	8.850	4.010	1.767	240.443	1.345	0.495	7.187

Note: * $P < 0.05$, **$P < 0.01$, ***$P < 0.001$

Table 4.14: Correlations between Average Public Exam Mark and background variables

Research Question 2: Factors Affecting School-Based Achievement

Does MBL use affect student achievement on school-based evaluation? As noted previously, this variable may be the more reliable and valid indicator of physics achievement. Table 4.15 shows the Pearson correlations between school-related factors, MBL use, Physics 2204 mark and the average school mark. The results indicate that significant correlations exist between school location and school enrolment (-0.527, $p < 0.001$), and average school mark and average Physics 2204 mark (0.703, $p < 0.001$).

	average school mark	school location	school enrolment	current MBL use	average Physics 2204 mark
average school mark	1.000				
school location	-0.175	1.000			
school enrolment	0.070	-0.527***	1.000		
current MBL use	0.101	-0.018	-0.035	1.000	
average Physics 2204 mark	0.703***	-0.038	-0.026	0.202	1.000
Mean	70.3387	1.5821	398.7015	1.4179	72.5610
Standard Deviation	7.2661	0.4969	237.6527	0.4969	7.2177

Note: * P < 0.05, **P < 0.01, ***P < 0.001

Table 4.15: Correlations between Average School Mark and school-related background variables

Table 4.16 shows the results of the regression analysis performed on the average school mark using school-related background variables. The regression model was significant at the $p < 0.001$ level and explained 51.8% of the variance in the independent variable. Only one variable the average Physics 2204 mark was significantly related to the school mark. The beta weight of average Physics 2204 mark (0.707) was high, which indicates that teachers of Physics 2204 and Physics 3204 produce consistent class averages. The other school-related background variables did not reveal any significant effect on the regression model.

Dependent Variable: ***Average School Mark***

Independent Variable	B	SE B	Beta	T	Sig T
school location	-2.097	1.520	-0.143	-1.379	0.173
school enrolment	$3.364x10^{-4}$	0.003	0.011	0.106	0.916
current MBL use	-0.647	1.317	-0.044	-0.491	0.625
average Physics 2204 mark	0.711	0.091	0.707	7.839	0.000

Multiple R	0.720	F value	16.668
R Square	0.518	Sig. of F	0.000
Standard Error	5.2040		

Table 4.16: Multiple regression between Average School Mark and school-related background variables

Table 4.17 shows the Pearson correlations between teacher-background factors, MBL use, Physics 2204 mark and the average school mark, and Table 4.18 shows the results of the regression analysis performed on the average school mark using teacher-background variables. The regression model was significant at the $p < 0.001$ level and explained 51.6% of the variance in the dependent variable. Again, the average Physics 2204 mark was the only significant factor related to the average school mark. The high beta weight for average Physics 2204 mark indicates why this model is significant and can explain 51.6% of the variance in the average school mark. The other teacher-background variables did not reveal any significant effect on the regression model.

	average school mark	years teacher micro experience	teacher's major	years teaching experience	teacher certification	current MBL use	average Physics 2204 mark
average school mark	1.000						
years teacher micro experience	-0.001	1.000					
teacher's major	-0.096	-0.124	1.000				
years teaching experience	0.090	-0.229*	-0.229*	1.000			
teacher certification	0.003	0.268*	-0.143	0.116	1.000		
current MBL use	0.078	-0.442***	0.214*	0.270*	0.098	1.000	
average Physics 2204 mark	0.693***	-0.200	-0.020	0.071	-0.177	0.221*	1.000
Mean	70.6658	2.6935	1.4516	13.8226	5.4677	1.4194	72.9608
Standard Deviation	7.1326	0.8979	0.5017	7.9970	1.6268	0.4975	7.0172

Note: * $P < 0.05$, **$P < 0.01$, ***$P < 0.001$

Table 4.17: Correlations between Average School Mark and teacher-background variables

Dependent Variable: *Average School Mark*

Independent	B	SE B	Beta	T	Sig T
years teacher micro	0.825	0.900	0.104	0.916	0.364
teacher's major	-0.395	1.457	-0.028	-0.271	0.787
years teaching	0.053	0.093	0.059	0.569	0.572
teacher certification	0.446	0.458	0.102	0.975	0.334
current MBL use	-0.859	1.660	-0.060	-0.517	0.607
average physics	0.752	0.101	0.740	7.483	0.000
Multiple R	0.719		F value	9.791	
R Square	0.516		Sig. of F	0.000	
Standard	5.2232				

Table 4.18: Multiple regression between Average School Mark and teacher-background variables

Table 4.20 shows the Pearson correlations between classroom-related factors, MBL use, Physics 2204 mark and the average school mark, and Table 4.19 shows the results of the regression analysis performed on the average school mark using classroom-related background variables. The regression model was significant at the $p < 0.001$ level and explained 58.3% of the variance in the dependent variable. Average Physics 2204 mark was the only significant factor related to the average school mark. The other teacher background variables did not reveal any significant effect on the regression model. For this exploratory research, however, it can be argued that student lab time has an acceptable significance (p = 0.052). The negative beta weight of student lab time (-0.180) indicates teachers who spend less time doing lab activities are more likely to produce students with higher school marks. What at first appears to be a surprising relationship could simply be the result of spending more time reviewing for evaluations or at "seat work" than hands-on physics.

Dependent Variable: *Average School Mark*

Independent Variable	B	SE B	Beta	T	Sig T
average Physics 2204 mark	0.780	0.092	0.746	8.481	0.000
student lab time	-2.652	1.336	-0.180	-1.985	0.052
current instruct uses (w/o MBL)	-0.527	0.571	-0.094	-0.923	0.360
current MBL use	0.749	1.508	0.050	0.497	0.621
teacher computer use attitude	-0.086	0.552	-0.014	-0.157	0.876

Multiple R	0.764	F value	16.245
R Square	0.583	Sig. of F	0.000
Standard Error	4.9771		

Table 4.19: Multiple regression between Average School Mark and classroom-related background variables

	average school mark	average Physics 2204 mark	student lab time	current instruct uses (w/o MBL)	current MBL use	teacher computer use attitude
average school mark	1.000					
average Physics 2204 mark	0.733***	1.000				
student lab time	-0.140	0.077	1.000			
current instruct uses (w/o MBL)	-0.066	0.086	0.315	1.000		
current MBL use	0.121	0.226*	0.278*	0.481***	1.000	
teacher computer use attitude	0.053	0.151	0.143	0.268*	0.100	1.000
Mean	70.4373	72.6047	1.5469	8.4531	1.3906	6.5313
Standard Deviation	7.3989	7.0767	0.5017	1.3205	0.4917	1.1948

Note: * $P < 0.05$, **$P < 0.01$, ***$P < 0.001$

Table 4.20: Correlations between Average School Mark and classroom-related background variables

The multiple regression analysis completed on average school mark indicates that only the average Physics 2204 mark had a significant effect. For this exploratory research the significance of student lab time is acceptable and will be included in the final regression model for this independent variable. Other variables, however, were selected because they were the most significant (although not meeting the $p < 0.05$ level) and were considered potentially confounding variables.

Table 4.22 shows the Pearson correlations between background variables, MBL use, average Physics 2204 mark and the average school mark, and Table 4.21 shows the results of the regression analysis performed on the average school mark using background variables. The regression model was significant at the $p < 0.001$ level and explained 61.2% of the variance in the average school mark. As seen in the first research question (pertaining to average physics public exam mark), the average Physics 2204 mark is a powerful factor influencing Physics 3204 achievement. The other background variables, including MBL use, did not reveal any significant effect on the regression model. Student lab time, however, appeared to be a confounding variable which affected student physics achievement. It was a significant factor affecting the average school-based mark when controlling for classroom factors and, when regressed in the summative analysis, its significance was 0.093. Although not meeting the required 0.05

level, it suggests a relationship with physics achievement masked by other variables. Investigating this relationship, if any, is outside this research and will be left for further study.

Dependent Variable: *Average School Mark*

Independent	B	SE B	Beta	T	Sig T
years teacher micro	0.917	0.891	0.110	1.029	0.308
teacher certification	0.491	0.405	0.116	1.212	0.231
school location	-0.996	1.439	-0.066	-0.692	0.492
student lab time	0.869	0.509	0.156	1.709	0.093
average Physics	0.808	0.091	0.774	8.870	0.000
current MBL use	0.495	1.619	0.033	0.306	0.761

Multiple R	0.78215	F value	14.44381
R Square	0.61175	Sig. of F	0.000
Standard	4.92464		

Table 4.21: Multiple regression between Average School Mark and background variables

	average school mark	years teacher micro experience	teacher certification	school location	student lab time	average Physics 2204 mark	current MBL use
average school mark	1.000						
years teacher micro experience	0.035	1.000					
teacher certification	0.134	0.282*	1.000				
school location	-0.176	-0.343**	-0.361**	1.000			
student lab time	0.062	0.128	0.074	-0.095	1.000		
average Physics 2204 mark	0.733***	-0.176	-0.068	-0.019	-0.144	1.000	
current MBL use	0.122	-0.439***	0.126	-0.034	-0.341**	0.225*	1.000
Mean	70.444	2.677	5.371	1.581	4.274	72.632	1.403
Standard Deviation	7.505	0.901	1.767	0.497	1.345	7.187	0.495

Note: * $P < 0.05$, **$P < 0.01$, ***$P < 0.001$

Table 4.22: Correlations between Average School Mark and background variables

Research Question 3: Factors Affecting MBL use

What factors effect MBL use? Survey results show that 55.3% of the teachers who responded considered themselves users of MBL. Although MBL use had the second highest computer usage rate, this level is far below what the teachers thought was ideal (97.3% thought high usage was ideal). The lack of any relationship between MBL use and physics achievement may be attributed to the low, or sporadic amount of actual MBL activities.

Table 4.23 shows the Pearson correlations between school-related factors and MBL use. The results indicate only the expected significant correlation between school location and school enrolment (-0.520, $p < 0.001$). The correlation confirms that it is more likely that larger schools are located in urban areas.

Table 4.24 shows the results of the regression analysis of school-related background variables performed on the independent variable MBL use. The regression model was not significant, therefore, suggesting that school factors are not related to MBL use. The typical explanation for low MBL use, lack of resources (which is usually attributed to small, rural schools), is not substantiated by this multiple regression

	current MBL use	school location	school enrolment
current MBL use	1.000		
school location	-0.001	1.000	
school enrolment	-0.085	-0.520***	1.000
Mean	1.4474	1.6184	383.8553
Standard Deviation	0.5005	0.489	232.3502

Note: * $P < 0.05$, **$P < 0.01$, ***$P < 0.001$

Table 4.23: Correlations between Current MBL Use and school-related background variables

Dependent Variable: ***Current MBL Use***					
Independent Variable	B	SE B	Beta	T	Sig T
school location	-0.064	0.140	-0.062	-0.458	0.649
school enrolment	<0.001	0.000	-0.117	-0.859	0.393
Multiple R	0.100		F value	0.369	
R Square	0.010		Sig. of F	0.692	
Standard Error	0.5048				

Table 4.24: Multiple regression analysis results for background school-related variables on Current MBL Use

Table 4.25 shows the Pearson correlations between teacher-background variables and current MBL use, and Table 4.26 shows the results of the regression analysis performed on the current MBL use using teacher-background variables. The regression model was significant at the $p < 0.001$ level and explained 31.5% of the variance in the dependent variable. Two variables, years teacher microcomputer experience and teacher major, were significantly related to MBL use. The beta weight of years teacher microcomputer experience (-0.425) indicates that teachers who have a high level of microcomputer experience were more likely to be MBL users. The beta weight of teacher major (0.114) indicates that teachers with a post-secondary background in the physical sciences were more likely to be MBL users. The other teacher-background variables did not reveal any significant affect on the regression model; however, for this exploratory research it can be argued that teacher certification has an acceptable significance ($p = 0.06$). The beta weight of teacher certification (0.223) shows that teachers with lower certification levels are more like to be MBL users.

	current MBL use	years teacher micro experience	teacher's major	years teaching experience	teacher certification
current MBL use	1.000				
years teacher micro experience	-0.442***	1.000			
teacher's major	0.214*	-0.124	1.000		
years teaching experience	0.270*	-0.229*	-0.229*	1.000	
teacher certification	0.098	0.268*	-0.143	0.116	1.000
Mean	1.4194	2.6935	1.4516	13.8226	5.4677
Standard Deviation	0.4975	0.8979	0.5017	7.997	1.6268

Note: * $P < 0.05$, **$P < 0.01$, ***$P < 0.001$

Table 4.25: Correlations between Current MBL Use and teacher-background variables

Dependent Variable: *Current MBL Use*

Independent Variable	B	SE B	Beta	T	Sig T
years teacher micro experience	-0.236	0.066	-0.425	-3.552	0.001
teacher's major	0.237	0.114	0.239	2.081	0.042
years teaching experience	1.255×10^{-2}	0.007	0.202	1.703	0.094
teacher certification	6.810×10^{-2}	0.036	0.223	1.918	0.060

Multiple R	0.562	F value	6.563
R Square	0.315	Sig. of F	0.000
Standard Error	0.4258		

Table 4.26: Multiple regression analysis results for teacher-background variables on Current MBL Use

Table 4.27 shows the Pearson correlations between classroom-related variables and MBL use, and Table 4.28 shows the results of the regression analysis performed on the MBL use using classroom-related variables. The regression model was significant at the $p < 0.001$ level, however, it only explains 26.5% of the variance in MBL use, which leaves 73.5% unexplained. The beta weight (0.458) of the only significant variable, current instructional uses (w/o MBL), indicates that teachers who utilize the computer for instruction in other modes are more likely to be MBL users as well. This high beta weight and level of significance suggests that MBL use is closely related to overall instructional computer usage. In other words, teachers are either computer users, in many modes of physics instruction (of which MBL is one part), or they are complete nonusers. The other classroom-related variables did not reveal any significant effect on the regression model. Most notable student lab time, often considered related to MBL use, was not a significant factor.

	current MBL use	student lab time	current instruct uses (w/o MBL)	teacher computer use attitude
current MBL use	1.000			
student lab time	0.279^{**}	1.000		
current instruct uses (w/o MBL)	0.481^{***}	0.234^{**}	1.000	
teacher computer use attitude	0.087	0.130	0.284^{**}	1.000
Mean	1.4247	1.5479	8.3973	6.4658
Standard Deviation	0.4977	0.5011	1.4312	1.1436

Note: $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$

Table 4.27: Correlations between Current MBL Use and classroom-related background variables

Dependent Variable: *Current MBL Use*

Independent Variable	B	SE B	Beta	T	Sig T
student lab time	0.179	0.106	0.18	1.696	0.094
current instruct uses (w/o MBL)	0.159	0.038	0.458	4.161	0.000
teacher computer use attitude	-2.904×10^{-2}	0.047	-0.067	-0.618	0.538
Multiple R	0.515		F value	8.293	
R Square	0.265		Sig. of F	0.000	
Standard Error	0.4359				

Table 4.28: Multiple regression analysis results for classroom-related background variables on Current MBL Use

Further analyzing the three multiple regressions reveals that school-related factors have little significant relationship with MBL use. Conversely, both classroom-related and teacher-background variables produced significant multiple regression models that could account for 26.5% and 31.5% (respectively) of the variance in MBL use. For this reason school-related variables were omitted from the final multiple regression model for the variable MBL use. All previously significant factors (years teacher microcomputer experience, teacher's major and current instructional computer use w/o MBL) were included, as well as the most promising variables: student lab time ($p = 0.094$), years teaching experience ($p = 0.094$), and teacher certification ($p = 0.060$).

Table 4.30 shows the Pearson correlations between background variables and MBL use. The results indicate that several significant correlations exist between background variables and MBL use. Further examination reveals that, besides teacher's major, the same variables that significantly correlate with MBL use also significantly correlate with current instructional computer use (w/o MBL). This further strengthens the statement that MBL use and overall instructional computer use are closely related.

Table 4.29 shows the results of the multiple regression analysis performed on MBL use using background variables. The regression model was significant at the $p < 0.001$ level and explained 46.4% of the variance in MBL use. Five of the six variables entered were significant at the $p < 0.05$ level. The strongest factor, with a beta weight of 0.292, was current instructional computer use (w/o MBL), which indicates that teachers who already utilize the computer for other instructional needs will more likely utilize it for MBL purposes. This multiple regression also indicates that a teacher who likely uses MBL will have a lower than average teacher certification, will have an academic background in the physical sciences, and will have a more than average number of years microcomputer experience. Furthermore, this teacher will most likely spend a greater amount of instructional time doing laboratory physics activities. The other background variable, years teaching experience, did not reveal any significant effect on the regression model.

	current MBL use	teacher certification	teacher's major	current instructional uses (w/o MBL)	years teacher micro experience	years teaching experience	student lab time
current MBL use	1.000						
teacher certification	0.133	1.000					
teacher's major	0.310**	-0.090	1.000				
current instructional uses (w/o MBL)	0.489***	-0.160	0.174	1.000			
years teacher micro experience	-0.452***	0.181	-0.276**	-0.415***	1.000		
years teaching experience	0.282**	0.125	-0.141	0.329**	-0.125	1.000	
student lab time	-0.326**	0.057	-0.097	-0.211*	0.174	-0.054	1.000
Mean	1.443	5.543	1.471	8.400	5.507	13.500	4.286
Standard Deviation	0.500	1.567	0.503	1.459	3.991	7.872	1.320

Note: * P < 0.05, **P < 0.01, ***P < 0.001

Table 4.30: Correlations between Current MBL Use and background variables

Dependent Variable: *Current MBL Use*					
Independent	B	SE B	Beta	T	Sig T
teacher certification	0.077	0.031	0.240	2.501	0.015
teacher's major	0.208	0.098	0.209	2.117	0.038
current instructional	0.100	0.038	0.292	2.659	0.010
years teacher micro	-0.033	0.013	-0.263	-2.497	0.015
years teaching	0.009	0.006	0.141	1.384	0.171
student lab time	-0.077	0.036	-0.204	-2.155	0.035

Multiple R	0.68139	F value	9.10034
R Square	0.46430	Sig. of F	0.000
Standard Error	0.38323		

Table 4.29: Multiple regression analysis results for background variables on Current MBL Use

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary of Analysis

This research was designed to investigate the effect of student Microcomputer Based Laboratory activities on achievement in Physics 3204. Achievement in Newfoundland's 3000 level science courses was measured by averaging school-based, and public exam marks. Each individual value, however, indicates a different type of physics achievement. The school-based mark is calculated, by the teacher, from various classroom evaluations such as, unit tests, quizzes, assignments, and laboratory work. It represents a broader physics achievement that encompasses such practical skills as experimenting, graphing, observing, and so on. On the other hand, the public exam mark, produced by the Department of Education, describes achievement on a validated, criterion referenced, summative evaluation. This exam emphasizes mathematical problem solving, knowledge and understanding of fundamental physics concepts.

To explore any affect MBL may have on achievement, it is necessary to include both measures as dependent variables.

Associated variables, the most important being the actual level of student MBL use, may, however, conceal MBL's affect on these two measurements of achievement. This research was designed, therefore, to control for classroom, teacher, and school factors, as well as investigate how these affect actual MBL use. Microcomputer Based Laboratories have only recently been introduced and promoted within the Newfoundland and Labrador school system; consequently, the level of MBL use may be so low that its affect on overall achievement is currently unmeasurable. To explore this, a third independent variable, current MBL use, was included within the research. If MBL proves to be associated with physics achievement then it is important to identify what conditions encourage its use. If MBL has no significant effect, then it is equally important to examine the level of MBL use to determine why it had no affect, and what educators may do to increase its use.

Analysis of research question one, "factors affecting public exam achievement", did not determine any significant relationship between current MBL use and the average public exam mark. When controlling for school-related factors, current MBL use did show a significant relationship (beta = -0.208 indicating users were more likely to have higher average public exam marks, $p < 0.05$), however, this relationship was not evident in the summative multiple regression. In the summative regression the only two variables that indicated a significant relationship were, years teacher microcomputer experience (beta = 0.230), and average physics 2204 mark (beta = 0.687). Notable, is the powerful and significant affect that pre-physics 3204 ability (as measured by average physics 2204 mark) has on the average public exam mark. Teachers with students that have done well in physics before will more likely produce a higher average public exam mark. This relationship is also very evident when analyzing research question two.

Except pre-physics 3204 ability, analysis of research question two, "factors affecting school-based achievement", also did not indicate any significant relationship (meeting $p < 0.05$) between classroom, teacher. school factors and the average school-based mark. For this exploratory research. student lab time was considered a predictor of average school-based mark while controlling for classroom factors. Teachers who spend less time doing laboratory activities were more likely to have higher average school-based marks. This relationship, however, was not substantiated in the summative multiple regression analysis for average school-based mark. Furthermore, the summative multiple regression, as with average public exam mark. did not show any significant relationship between current MBL use and the average school-based mark. Based on these analyses, therefore, current MBL use has no significant relationship with physics achievement. Examining the current level of MBL use (55.3% of teachers responded they were users) is necessary, therefore, to perhaps gain further insight.

Analysis of research question three, "factors affecting MBL use", indicated that teacher and classroom factors were predominantly responsible for the level of MBL use. The final multiple regression determined that teacher's certification level, teacher's academic background, current instructional computer uses (excluding MBL), teacher's microcomputer experience, and student lab time are significantly related to current MBL use. Teachers who are more likely to be MBL users, therefore, have many similar characteristics such as; a lower than average teacher certification level; a post-secondary degree in the physical sciences; and; more than 5½ years of microcomputer experience. During instruction these teachers spend a greater than average amount of time doing laboratory work .and, are already using the microcomputer for other instructional needs. The regression analysis clearly indicates that a teacher's years experience, where they teach (i.e., rural or urban community), and the school size have no significant impact on the level of MBL use.

Conclusions

Physics Achievement

This research suggests the only significant predictor of student performance in level three physics is their previous physics achievement. It is very likely that students study both Physics 2204 and 3204 under identical conditions, that is, the same teacher, school environment, and so on. Whatever enables or assists students to learn Physics 2204, for example, math ability, school resources, etc., are still present when they are learning Physics 3204, hence they perform similarly. Surprisingly, however, school factors (enrolment, geography), teacher factors (academic background, years experience, certification level) and classroom factors (laboratory time) did not significantly predict achievement. These results appear to contradict several widely-held suppositions about the Newfoundland education system.

Delineating what casual factors actually result in better student physics achievement is outside this thesis, however, it has long been argued that larger, better equipped schools located in urban centers provide better educational opportunities and produce higher achieving students. The results of this research do not support this premise. Furthermore, the notion of more experienced, better educated teachers producing higher achievers is also not supported. The conditions that provide an optimum learning environment for physics are obviously more numerous and diverse than merely teacher qualification and physical surroundings.

Microcomputer Based Laboratories

Based on this research neither the average public exam mark nor average school-based mark is significantly related to the current MBL use in Newfoundland and Labrador schools. This research concludes, therefore, that at the present level of use, Microcomputer Based Laboratory activities have no significant influence on student school-based and public exam marks. Before definitively stating that MBL has no affect on student physics achievement, though, the issue of its use must be further explored.

Firstly, under the broad definition presented in this research (a minimum of 2 to 5 MBL activities a year), only 55.3% of teachers were classified as a MBL user. While this percentage appears high (second highest category of computer use, see chart 4.17) in fact it does not represent a high level of MBL usage considering this research did not explore MBL use details pertaining to the duration of activities, their topic and method of delivery. Perhaps activities performed may have been short, 15-minute confirmations of established principles, rather than the student-directed explorations discussed throughout education literature. A particular teacher may complete three MBL activities, hence classified as a user, however, they occur within one unit of study (for example, mechanics). This may bring about improved physics achievement in the area of mechanics; on the other hand, it wouldn't have profound affects on comprehensive, summative evaluations. It is unlikely that 2 to 5 short MBL treatments completed in a school year, perhaps concentrated in one area, would have a measurable affect on the students' public or school-based marks. The potential benefits of MBL, however, are understood by teachers, since 97.3% responded that being a MBL user was ideal. The possibility exists, therefore, that MBL's beneficial affects on student physics achievement have been unrealized because of a low level of teacher use. Consequently, if the introduction of MBL is to be worthwhile, factors affecting current MBL use must be investigated and information gathered to guide any promotion of MBL usage.

This study indicates that current MBL use is not related to the school factors enrolment and geography (which are associated with the level of school resources and the socio-economic background of it's students). A possible reason given for low use; (lack of MBL materials) therefore, is unsubstantiated.

Both large schools (with more financial ability) and small schools (typically with limited resources) have equal access to the necessary materials for MBL. It is unlikely, however, that all schools within the sample are sufficiently equipped to fully implement MBL. This may be the result of individual school or teacher priorities that do not highly value MBL; therefore, choose not to purchase the equipment. In summary, those teachers and schools who feel MBL is an important part of the physics curriculum usually equip themselves.

A highly significant relationship exists between current MBL use and the teacher-related factors; namely; certification level, academic background, microcomputer experience, current instructional computer use, and current laboratory time. Teachers who are most likely to be MBL users have an academic background in the physical sciences, greater than 5½ years computer experience, level five teacher certification, currently utilize the computer to aid instruction, and, spend more time doing laboratory activities. Teacher attitude toward computer instructional integration is not a significant consideration, since 96.1% have the attitude that moderate to high computer use is ideal. It appears that teachers who have a strong physics background, moderate computing skills, and, training on instructional computer use and the role of practical science experiences within the curriculum, possess fundamental skills that the typical MBL user requires. Future research must confirm and/or determine, however, these characteristics and essential skills which are common to the MBL user's. Understanding the specific skills and abilities can ensure that future teacher training and inservice will be more successful. For example; to have greater than 5½ years computer experience, i.e., moderate computing skills, does not define what specific computer abilities teachers possess that enable them to be MBL users. MBL use, therefore, requires re-emphasis on teacher skills, not teacher attitudes and school resources. This re-emphasis can potentially shape post secondary education programs and curriculum inservice for science teachers, as well as school district hiring practices.

Recommendations for Further Research

This research has endeavoured to explore the relationship between microcomputer based laboratory activities and physics achievement. Being exploratory in nature, it has raised many questions that require further research. Subsequent conclusions may indeed be significant enough to shape the Department of Education's future science curricula development. Some worthwhile areas of further research are:

1. An investigation of the relationship between MBL duration and level of physics achievement.

2. An examination of the level of computer skills common to teachers that have successfully integrated MBL.

3. The relationship of microcomputer based laboratories with other instructional computer uses.

4. An examination of perceived hindrances to MBL use.

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APPENDIX A

TEACHER

SURVEY

By K. D. Bradley Clarke, Memorial University

90 Cowan Ave.
St. John's, NF
A1E-3P3

1993 05 25

teacher's name
school name
community
postal code

Dear *teacher's name*:

I am presently completing my master's programme in Curriculum (Science) at MUN. I have done all the course work and need only to finish my Thesis: *Factors affecting Physics achievement.*

To complete this thesis I must have certain information from a sampling of schools throughout the province. You and your school, *school name*, have been selected for me by the Provincial Department of Education. I have prepared a brief survey for the selected schools to complete and return.

I realize that this is a **VERY** busy time of year for you, and therefore anything extra is an imposition on you - but the information required is **absolutely vital** to me. Without the information my thesis will be put on hold till the fall.

Would you please complete the questionnaire and return it at your very earliest convenience. I shall be very grateful, and much obliged.

Yours sincerely,
(and expectantly)

Bradley Clarke

SURVEY OF PHYSICS TEACHERS

School: *school name*
Name:

RESOURCES

Do you have experience using computers (for any purpose)?

If you do, how long have you been using computers?

How many computer stations are available for your physics classes?

What software is available for physics instruction?

-word processors	-databases
-spreadsheets	-Vernier/Super Champ
-Other (please list)	

EXTENT OF COMPUTER USE

The following is a series of questions that will determine the extent you use computer technology to aid Physics instruction. Please mark the response that best describes your situation or attitudes.

The frequency of use categories is based upon a ten-month school year. The categories are: (1) once a day, (2) once a week, (3) once a month, (4) 2 to 5 times a year, (5) once a year, and, (6) never.

SCALE:

(1)-once a day (2)-once a week (3)-once a month
(4)-2 to 5 times a year (5)-once a year (6)-never

1. Demonstration Programs. These programs are used in the same way as blackboards and films are used, to illustrate a concept for an entire class. Examples: *Making waves*, or *Artillery*.

A. Which best describes **your current frequency of use** of demonstration programs for physics instruction: **1 2 3 4 5 6**

B. Which best describes what you believe **the ideal frequency of your use** of demonstration programs for physics instruction should be: **1 2 3 4 5 6**

2. Drill-and-Practice. The use of computer programs to memorize facts, such as formulae. Example; multiple choice software.

A. Which best describes **your students' current frequency of use** of drill-and-practice programs for physics instruction: **1 2 3 4 5 6**

B. Which best describes what you believe **the ideal frequency of your students' use** of drill-and-practice programs for physics instruction should be: **1 2 3 4 5 6**

3. Laboratory Simulation Programs. These programs simulate laboratory experiments on a computer system. Examples: *Gravity* or *Newton's Law*.

A. Which best describes **your students' current frequency of use** of laboratory simulation programs for physics instruction: **1 2 3 4 5 6**

B. Which best describes what you believe **the ideal frequency of your students' use** of laboratory simulation programs for physics instruction should be: **1 2 3 4 5 6**

4. Tutorials. These programs provide explicit content instruction to students. Example; text-and-question software.

A. Which best describes **your students' current frequency of use** of tutorial programs for physics instruction: **1 2 3 4 5 6**

B. Which best describes what you believe **the ideal frequency of your students' use** of tutorial programs for physics instruction should be: **1 2 3 4 5 6**

5. Classroom Management Programs. These programs help with the administration of daily teaching. Examples: word processors, spreadsheets, or data bases.

A. Which best describes **your current frequency of use** of classroom management programs for physics instruction: **1 2 3 4 5 6**

B. Which best describes what you believe **the ideal frequency of your use** of classroom management programs for physics instruction should be: **1 2 3 4 5 6**

6. Laboratory Tool. The use of computers, along with additional interfaces, to capture, store, analyze and display experimental data. Examples: *Super Champ, Vernier.*

A. Which best describes **your students' current frequency of use** of computers as a laboratory tool for physics instruction: **1 2 3 4 5 6**

B. Which best describes what you believe **the ideal frequency of your students' use** of computers as a laboratory tool for physics instruction should be: **1 2 3 4 5 6**

LABORATORY AND COMPUTER USE

1. While completing the requirements for a unit of work in Physics 3204: on average **how many hours** are spent doing practical laboratory work? **Never ½ 1 2 3 More**

2. While doing laboratory work: how large are the student groups? **Whole Class 10 5 2 less**

3. Rank in order the following computer applications starting with the one **most** used and ending with the least used.

__ Photogate Interface
__ Ammeter Interface
__ Dynometer Interface
__ Word Processors
__ Thermometer Interface
__ Voltmeter Interface
__ Graphing Utilities

4. If you use computer interfacing to aid physics instruction rank the following applications from most to least used.

__ Demonstrations
__ Classroom Instruction
__ Enrichment
__ laboratory
__ Remediation

GENERAL

1. What was your undergraduate major?

2. What was your undergraduate minor?

3. How many years have you taught? physics?

4. When planning your course of instruction for Physics 3204 which text did you decide to use?

__ Fundamentals of Physics __ Physics for a Modern World

5. Please indicate the order you taught the units of Physics 3204:

___ Unit I *Vector Kinematics*
___ Unit II *Dynamics*
___ Unit III *Electrostatics*
___ Unit IV *Current Electricity*
___ Unit V *Magnetism, Electromagnetism and Electromagnetic Induction*
___ Unit VI *Elective*

6. Which elective unit(s) did you complete?

Thank-you for Your Assistance

APPENDIX B

NOTES ON METHOD OF ANALYSIS

December 1, 1999

To: Brad Clarke

From: Jeff Bulcock

RE. **Notes on Binary Dependent Variables**

Gerry asked me to comment on your Nov. 24th memo re. the appropriate estimator to use in a model where all the X's are continuous and the Y is binary (dichotomous).

*[**Historical Aside:** In 1955 my brother, Donald Bulcock, and his professor, Dr. M.G.Kendall, were the first to program a computer to estimate a two-group discriminant function. They used Assembly language because the computer at the London School of Economics was short in the memory department. Fortran soon took over but had not been invented in 1955.]*

For the reasons which follow I, personally, do not use two-group discriminant function analysis (DA). Like you (and Gerry) I use regression analysis within the general linear model (GLM). **Bear in mind the following four points.**

Point 1. In 1951 an obscure psychologist called S.S.Stevens wrote a book on experimental psychology in which he identified the scales of measurement: namely, nominal, ordinal, interval, and ratio. Every introductory stat text since that date has dutifully followed the Stevens's classification. Unfortunately, the nominal scale is not a scale at all. To scale there has to be dimensionality. The so-called nominal scale lacks this property. All it does is to label an item – usually present or not present (1 or 0). The numbers on the backs of hockey players, for example, constitute a nominal scale, but they have no meaning except as convenient labels.

An interesting feature of the dichotomous or binary *nominal* variable is that unlike most nominal variables (e.g., 1=RC, 2=Ang., 3=UC, 4=SA, 5=PA and 6=other) which lack dimensionality, the dichotomy has two values such as 1 or 2, 1 or 0; and it is this feature that gives it the missing property. Consider gender where male = 1 and female = 2. The distance between 1 and 2, male and female, is the same as the distance between 2 and 1, female and male.

But the distance between any adjacent numbers is the same as the distance between any other pair of adjacent numbers. The classic example is the centigrade thermometer. Note that the underlined sentence above is what Stevens called the interval level of measurement. Given the definition we are justified in treating dichotomous (yes,no) variables as interval scale variables. With interval scale variables we can calculate the mean, variance and covariances which about covers most of the key concepts in statistics; in other words we can use every known statistical technique including DA for the estimation of equations using binary coded dependent or independent variables.

When X and Y are both continuous we use Pearson product-moment correlation. When X is dichotomous and Y continuous the text books advise us to use point biserial correlation. And when X and Y are both dichotomous the text book recommends analysis using the phi coefficient. But, in fact, all three forms are identical, which means that all can be calculated using the Pearson product-moment procedure.

Point 2. The multivariate form of the general linear model (GLM) encompasses eight mathematical models, the fourth of which is the DA model. The models are as follows:

1) all X's continuous, the Y continuous (multiple regression);
2) all X's discrete, Y continuous (ANOVA);
3) some X's discrete, some continuous, Y continuous (ANCOVA);
4) all X's continuous, Y dichotomous (two group discriminant function analysis);
5) all X's discrete, Y discrete (logit analysis);
6) some X's discrete, some continuous, Y dichotomous (binary logistic regression);
7) some X's discrete, some continuous, Y categorical (multinomial logistic regression);
8) some X's discrete, some continuous, Y ordinal (polytomous logic universal model).

Note that models 1 through 4 were taught as a component of the graduate program in education at MUN, though model 4 (DA) was introduced in its regression analysis incarnation. It is well known (e.g., Cohen and Cohen, 1975, p. 442) that the multiple regression analysis version of model 4 (all X's continuous, Y dichotomous) is statistically identical with canonical analysis because dichotomous variables are interval scales. Canonical analysis is a full multivariate form of GLM where all the X's are continuous and all the Y's are continuous. This means that it is also identical with the DA for two groups; i.e., the multiple regression equation is proportional to the discriminant function; which, in turn, means that both CA and DA are perfectly correlated with each other and both are perfectly correlated with the parallel multiple regression model.

Point 3. Even though two group DA and CA and the multiple regression model with dichotomous dependent variables are equivalent estimators, there are special problems which affect both. In the literature (e.g., Neter and Wasserman, 1974, pp. 322-334) they are identified as follows:

1) nonnormal error terms;
2) nonconstant error variance; and
3) constraints on response function.

The Clarke analysis addresses problems 2 and 3. For example, a solution to the second problem could be handled using weighted least squares (WLS). The WLS solution is only required, however, if the mean responses (Y's) range between approximately .2 and .8. Unless the mean of Y falls outside this range (i.e., below .2 or above .8) the error variance will not be sufficiently unequal as to make a WLS solution worth while. Clarke's mean response range for his MBL variable was between .45 and .55; hence, in that case the WLS solution was not necessary. The third problem, constraints on the response function, can be handled by making sure that the mean responses for the model do not fall below 0 or 1 for levels of X. Clarke's model automatically meets this constraint.

Problem 1 is different. Even if the error terms are not normal when the DV is binary, the least squares estimator still provides unbiased estimation which is asymptotically normal. When the sample size is large, as it is in the Clarke case, it is legitimate to make inferences concerning the regression coefficients on the valid assumption that the error terms are normally distributed.