TEACHER AND STUDENT ATTITUDES TOWARD MICROCOMPUTER-BASED LABORATORIES (MBLs) IN THE PROVINCE OF NEWFOUNDLAND AND LABRADOR

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W. ROBERT SWYER

Teacher and Student Attitudes Toward Microcomputer-Based Laboratories (MBLs) in the Province of Newfoundland and Labrador

W. Robert Swyer
MUN #8112385

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ABSTRACT

The purpose of this thesis was to determine teacher and student attitudes toward Microcomputer-Based Laboratories (MBLs) in the province of Newfoundland and Labrador. A sample consisting of 53 teachers and 59 students responded to survey instruments designed by the author.

The teacher instrument consisted of three sections. Section A had 7 multiple-choice items and was used to determine the extent of MBL use by teachers. Section B was composed of 34 statements that teachers responded to using a 5-point Likert scale. Section C was used to collect personal information.

The student instrument consisted of two sections. Section A was used to obtain some personal information from the students. Section B was composed of 30 statements that students responded to using a 5-point Likert scale.

The following questions guided the research:

1. To what extent have teachers and students used MBLs?
2. What are teachers' and students' attitudes toward MBL equipment and software?
3. Do teachers and students believe that MBL techniques enhance student learning?
4. Do teachers and students believe that MBL techniques enhance their physics courses?
5. Do teachers and students think that MBL techniques have affected students' attitudes toward science and computers?

6. How do teachers and students think the MBL approach can be improved here in the province?

7. Have MBL techniques affected teacher attitude toward computers?

The majority of teachers indicated that MBLs were used both by students and themselves to collect and analyze data. About 19% of teachers said that students used the MBL equipment and software on their own. A small percentage of teachers indicated that they only used MBLs in demonstrations with their classes. Most teachers used MBLs for 1/4 or less of the time they spent on labs. Approximately 21% of teachers were using MBLs between 1/4 and 1/2 of the time and about 17% of the teachers were using MBLs between 50% and 100% of the time they spent in the lab. Some teachers and students reported that MBLs have been used in other science courses.

Results from teacher and student surveys on the 5-point Likert statements indicate that teachers and students alike have overall positive attitudes toward MBLs with respect to MBL equipment and software, enhancing student learning, enhancing their physics courses, and affecting students' attitudes toward science and computers. As well, teacher attitude toward computers was positively affected. Teachers and students share the opinions that more computers should be assigned specifically to science labs, and that additional MBL equipment should be provided for use in the science lab. Also, teachers and students believe that MBLs should be used at least four or five times a year, and students, in general, would like to see MBLs used more often.

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CHAPTER 1

INTRODUCTION

In the last ten to fifteen years there has been a great increase in the number of microcomputers being used in our society. The business world, manufacturing world, and communications world have all been greatly changed due to this new "computer age".

The field of education is another area which has been greatly influenced by microcomputers. For example, most high schools in Canada offer a range of computer related courses. Some of these are at the structured programming level while others involve computer application areas such as CAD (computer-aided design), data management, and spread sheet analysis. Many primary, elementary, and junior high school teachers also use microcomputers in their classrooms. Some use subject specific software, while others are introducing their students to word processing, drawing, and graphics programs.

Videodisc and CD-ROM technologies are allowing computers to do even more within the school setting. Whole volumes of encyclopedias and other reference materials can be accessed quickly and conveniently with the advent of CD-ROMs, while videodisc players and computers can be combined to provide high resolution life-like images that can be actively manipulated by both students and teachers.

More recently, the Internet is being used for educational purposes. Teachers are communicating with colleagues, locating information for their courses, down loading lesson plans, and taking university courses all via the Internet. Students go "on-line" to find information for projects and papers and to interact and share information and ideas with their peers.

STATEMENT OF THE PROBLEM

Background

Microcomputers in Science Education

There are several ways in which a microcomputer can be used in science education.

1. Computer Assisted Instruction(CAI)

   There are a few distinct types of CAI. First, there are drill and practice programs which allow individual learners to improve their skill in some particular area which they have previously learned. Secondly, tutorial programs allow the learner to utilize written explanations, descriptions, problems, questions, and graphic illustrations for concept development. Thirdly, simulation programs allow the student to see and take part in "real world" experiences which would be difficult or impossible to duplicate in a classroom setting.

2. Data Processing

   Graphing programs, statistical packages, spread-sheet programs, and data-bases are examples of data processing software which students and teachers can use.

3. Word Processing / Graphics

Many students are now using software packages such as *Word Perfect* and *Harvard Graphics* to present their science projects, assignments, and laboratory write-ups.

4. Testing

Some teachers are using computer hardware and software to produce and/or administer tests. This simply replaces the paper and pencil method.

5. Teacher Assistance

Many teachers are using software packages to make their paper work and record keeping associated with teaching easier and less tedious.

6. Data Collection

Computer interface devices enable the microcomputer to detect many physical properties in the real world and the microcomputer, together with the appropriate equipment, becomes a powerful laboratory instrument for collecting and analyzing data.

Computer Interfacing / MBLs: The Basics

An interface device attached to a microcomputer, along with the appropriate equipment, can be used to investigate and explore many phenomena. Any laboratory in which the computer is used in this manner is known as a "Microcomputer-Based Laboratory" or "MBL". Computer interfacing in the science laboratory (MBLs), can probably be categorized into three main areas: timing, sensing, and analysis/reporting.

Timing

The microcomputer and interface unit can make precise timing measurements of many types of motion. This usually involves the use of either a photogate or a sonar device. The photogate utilizes a phototransistor whose "on/off" condition is detected by the computer and used to control timing information. The sonar device transmits high frequency sound and detects the resulting echo from which timing information is measured. Physical quantities such as position, velocity, acceleration, and reaction time can accurately be measured by the above techniques.

Sensing

Sensing basically involves the process of detecting a voltage from some source external to the computer. The analog to digital converter (ADC) is the main component of a sensing system. The ADC converts analog variables into digital values that can be manipulated by software. Any device that creates a voltage or alters one due to some external stimulus can be used as a sensor. An example of this is a thermistor which changes its resistance in response to a change in temperature. Another example is a photodiode which varies its output voltage depending on the incident light level. There are also many other types of sensing probes available that alter their characteristics in response to a stimulus.

Analysis/Reporting

The software that runs a computer interface includes options for the analysis and reporting of data. Graphing, linear regression, and simple statistics (such as determining the mean) are examples of such options. As well, the data and associated graphs can be reported to the computer screen or printed out.

Purpose of Study

There are many variables that could be studied with respect to MBLs. This author was interested in the affective domain since the evaluation of any innovative approach to teaching and learning should include assessments in this area. The purpose of this study, therefore, is to determine the attitudes of teachers and students toward MBLs in the province of Newfoundland and Labrador. In particular, the following questions will serve to guide the research.

1. To what extent have teachers and students used MBLs?
2. What are teachers' and students' attitudes toward MBL equipment and software?
3. Do teachers and students believe that MBL techniques enhance student learning?
4. Do teachers and students believe that MBL techniques enhance their physics courses ?
5. Do teachers and students think that MBL techniques have affected students' attitudes toward science and computers?
6. How do teachers and students think the MBL approach can be improved here in the province ?
7. Have MBL techniques affected teacher attitude toward computers?

Significance of the Study

The author of this thesis used a computer interface in a MBL situation several years ago while teaching two high school physics courses and has since been interested in the area. At the time, it was a relatively new way of approaching the laboratory component of the physics courses and is probably still regarded as a fairly new approach in the labs of the science courses taught in this province. Therefore, it would be interesting at this time to see what other teachers and students of the province think about the MBL approach. Also, few studies found in the literature focus on what teachers and students think about the MBL approach. As Kim (1989) pointed out, there have been a number of studies on MBLs in relation to student learning. However, most of them do not focus on the affective domain of MBL experiences.

Perhaps most importantly, as is the case with any teaching technique, "attitudes" are in themselves meaningful. For example, student attitudes, according to Simonson (1979), are significant for several reasons.

First, many studies have made a connection between attitudes and achievement. Simonson says that these connections are sometimes very vague but, "...probably the development of desirable attitude positions in learners should be a goal in itself" (p. 34).

Secondly, even if the relationship between attitudes and achievement is unclear, Simonson feels that "...it seems logical that students are more likely to remember information, seek new ideas, and continue studying when they act favorably to an instructional activity, or 'like' a certain content area" (p. 34).

Finally, Simonson says that attitudes toward a particular type of instruction can indicate whether or not this instruction has an impact on the student learning process. "In other words, we need to assess the opinions of our students toward the learning activities we are subjecting them to, if for no other reason than to improve the quality of our procedures" (p. 34).

Teachers' attitudes are also significant since they determine the framework of the teaching that takes place in the school and have a definite impact on students' learning and development. The teachers' interest, background, willingness to learn, enthusiasm, and understanding of material influence the attitudes of the students. For example, it is in many cases the teacher who is the introducer of computer techniques, and the level of success of computer use depends on the teacher (Reed, 1986). Clement (1981) says that if computer-based learning is going to happen, then the attitudes of teachers must be positive since they are critical to the process. If MBLs are going to take a place in the science courses of this province, then teachers must not only have positive attitudes toward them, but be willing to use them in their courses. We must, therefore, determine the attitudes that the teachers in this province have toward MBL technology.

Definition of Key Terms

Attitude

Milton Rokeach (1968) says that "An attitude is a relatively enduring organization of beliefs around an object or situation predisposing one to respond in some preferential manner" (p. 449).

Daniel J. Mueller (1986) adopts Louis Thurstones definition and says that "Attitude is 1) affect for or against, 2) evaluation of, 3) like or dislike, or 4) positiveness or negativeness toward a psychological object" (p. 3).

Computer Interfacing

Thomas Bross (1986) says "Computer Interfacing is providing a link between the real physical world and the internal electronic world of the microcomputer" (p.16).

Microcomputer-Based Laboratory (MBL)

Karen Walton (1985) reports that:

> MBL is an acronym coined by Robert F. Tinker, Director of Technical Education Research Centers (TERC). A microcomputer -based laboratory gathers data directly from the environment by means of low cost transducers. These devices measure physical properties (such as light and temperature), translate the measurements into computer-readable electrical currents, and then display them on the computer monitor (p.44).

In Bross (1986), the author states "An MBL (Microcomputer-Based Laboratory) is any laboratory that uses a microcomputer as a measuring instrument" (p.16).

Real-Time

Real-time operations are either those in which the machine's activities match the human perception of time or those in which computer operations proceed at the same rate as a physical or external process (Microsoft Press, 1991).

Traditional Laboratory

I. Scott MacKenzie (1988) states:

> The traditional science experiment does not use a computer. The students, provided with a set of objectives and procedures by their instructor, set up an experiment with laboratory apparatus, provide initial stimulus, and gather data with measurement instruments such as a stop watch, voltmeter, thermometer, scale, pH meter, etc. The data is analyzed and results summarized in graphs or tables and submitted in a Lab Report (p.12).

Limitations Of The Study

A major limitation of this study is the use of mail-out questionnaires. This type of survey technique typically has a low response rate. The researcher made every effort possible to ensure a good response rate. This included follow-up phone calls to all teachers being surveyed.

Another limitation concerns the fact that the researcher constructed the survey instruments. However, since comments and suggestions from experts in the field were considered, the researcher is optimistic that the instruments are valid and reliable.

Finally, as Borg and Gall (1989) point out, "...one must remember that attitude scales are direct self-report measures and so have the usual disadvantages of this type of instrument" (p. 312). They say that one of the primary disadvantages relates to the fact that "...we can never be sure of the degree to which the subjects responses reflect his or her true attitudes" (p.312). In addition, they note that a respondent's knowledge and expertise about the subject matter will play an important role. The researcher hopes that the teachers and students surveyed gave responses which reflect their attitudes.

CHAPTER 2

REVIEW OF THE RESEARCH LITERATURE

Much of the research literature on Microcomputer-Based Laboratories falls into three general categories. The first focuses on MBLs and graphing, the second considers MBLs as new tools of science for the development of concepts and scientific experimentation, and the third centres on teacher and student attitude toward MBLs.

MBLs And Graphing

Brasell (1987) describes a MBL study involving 93 secondary physics students who used sonar detectors in familiarization, prediction, and reproduction activities involving distance and velocity graphs. Four groups were used in her study: a "Standard-MBL" group in which data was graphed in real-time; a "Delayed-MBL" group where the data was graphed after being stored for approximately 20 seconds; a paper-and-pencil control group where students manually graphed descriptions of motions described on worksheets; and a "test-only" control group who did not participate in any of the motion activities.

Pretests and posttests were given to all groups and, overall, students in the Standard-MBL treatment performed significantly better than students in other treatments, particularly on the distance subtest. Brasell attributes this to the real-time graphing capabilities of the MBLs and believes that even a twenty or thirty second delay between the gathering and graphing of data diminishes the effect of a real-time MBL experiment. She did note that there was little improvement for any of the treatments when it came to the concept of velocity. Brasell concludes that "Real-time graphing of data appears to be a key feature for both cognition and motivation. It allows students to process information about a physical event and its graph simultaneously rather than serially"(p. 394).

Beichner (1990) did a study that involved a "VideoGraph" technique in which video images of an event are displayed "movie-like" on a screen along with appropriate graphs representing the event. In his opinion, this type of procedure will mimic real-time MBL exercises and, therefore, should show similar positive effects for the understanding of graphing as those suggested in Brasell (1987).

The researcher randomly assigned 237 high school and college students to one of five groups; group one used the VideoGraph method only; group two used the VideoGraph method and were also shown a physical demonstration of the projectile motion depicted on the computer; group three used a "traditional" method in which previously taken stroboscopic photographs of a projectile motion served as the source of data; group four used the traditional method as in group three but were also shown a physical demonstration of the projectile motion depicted in the stroboscopic photographs; and group five acted as a "test-only" group and did not take part in any of the graphing activities.

Results from pre- and posttest scores indicated that although the VideoGraph students had higher scores than students in other groups, the difference was not statistically significant. Beichner believes that it may not be the simultaneous viewing of an object's motion and associated graphs of that motion which is the key to real-time MBLs, but rather the fact that students can actively control the graphing taking place on the computer screen by adjusting the motion of a moving object.

Mokros and Tinker (1987) report on two preliminary studies and one longitudinal study involving MBLs. In the first study, they examined children's graphing skills and misconceptions and concluded that students make two main types of errors when it comes to viewing graphs. First, they see graphs as "pictures" and, secondly, they confuse slope and height.

The second study (also discussed in Mokros (1985)) focused on a five day MBL unit where sixth-grade students used their own body movements and the motion of a toy car to produce real-time graphs. Observations and quiz scores showed that "...after five days, they had developed solid graph interpretation skills..."(p. 374).

The third study was aimed at studying childrens' graphing skills over a three month period. Seventh and eighth graders used MBL techniques in science units on illusions, heat and temperature, sound, and motion. A multiple-choice test of graphing skills showed that "Scores on the 16 graphing items indicate a significant change in students' ability to interpret and use graphs between pre- and posttests"(p. 376). The authors also indicate that the "graph-picture" confusion was eliminated for many of the students after the MBL treatment.

In conclusion, Mokros and Tinker (1987) suggest four reasons as to why the MBL approach appears to be a powerful way of teaching graphing skills: (i) learning through

MBLs reinforces many learning modalities; (ii) the real-time capabilities of MBLs link the concrete experience and the symbolic representation of that experience; (iii) MBLs provide students with genuine scientific experiences in gathering and studying data; and (iv) MBLs reduce the drudgery of producing graphs.

Adams and Shrum (1990) investigated the effects that MBL exercises had on students' ability to construct and interpret line graphs. High school biology students were assigned to either an MBL group or a conventional group. The MBL group used a computer and temperature probe to collect and display graphs associated with heating and cooling exercises while the conventional group collected and graphed data using stopwatches, thermometers, and paper-and-pencil methods. Each of the groups, balanced in terms of cognitive development, gender, and graphing ability before the treatment, performed four one-hour experiments with water and/or ice and a Bunsen burner.

Results on pre- and posttests showed evidence that the conventional group out-performed the MBL group on graph construction skills. However, results on pre- and posttest graphing instruments showed no statistically significant differences in graph interpretation skills between the MBL and conventional groups, but, the authors say:

> An effect size (Glass et al., 1981) of 0.48 was, however, calculated from the scores on the graph interpretation portion of the I-TOGS instrument. This effect size is again over the 0.3 level usually associated with educational significance (Joyce et al., 1987) and, therefore, indicates that the learning that occurred on graph-interpretation skills during exposure of MBL exercises was worth the time and effort to implement it (p. 783).

Adams and Shrum conclude that over the course of treatments, the MBL group changed their attitude toward the computer. By the fourth exercise, instead of watching the graph being constructed as the experiment proceeded, they "trusted" the computer and used the time to perform other tasks.

A study by Stuessy and Rowland (1989) involved high school biology students who investigated temperature change of two solutions measured from freezing to boiling points. Students were randomly assigned to one of five groups; group one used a traditional thermometer and graphed results by hand; group two used a digital thermometer and graphed results by hand; group three used a digital thermometer and the results were keyed into a computer and graphed (delay-computer graph); group four used a temperature probe and computer to gather data and the data was then keyed into the computer and graphed (delay computer graph); and group five used a temperature probe and computer to gather data while the graphs were displayed in real-time on the screen.

Results on a content-test, designed by the author to test students' understandings of heat of fusion/vaporization concepts, showed that students in group one performed better than students in other groups, whereas results on a graphing-skills test (pre- and posttest), developed by the researchers, indicated the students in group five received better scores than students in other treatments. The authors suggest that "These results corroborate earlier research which support MBLs as being superior in enhancing the development of graphing abilities" (p. 21).

Nachmias and Linn (1987) investigated students' critical evaluation skills with respect to MBLs and graphing. One hundred and twenty four eighth graders took part in phase one of the study (fall semester) and used MBLs in 54 activities involving temperature, heat, and energy. The purpose of this phase was to define the problem, develop the measuring instruments, and assess students' critical evaluation skills. In the second phase (spring semester), 124 students were involved and the instruction was enhanced slightly by adding several class activities and a newer version of MBL software and hardware.

A CEG instrument (Critical Evaluation of Graphs) was given at the end of phase one and was then enhanced and given on a pre- and posttest basis in phase two. It was designed to establish how students evaluated MBL information and assessed five causes of invalid or unreliable graphs : 1) graph scaling; 2) probe setup; 3) probe calibration; 4) probe sensitivity; and 5) experimental variation.

Results from phase one showed that students improved in their abilities to detect invalid data due to errors in graph scaling, probe setup, and probe calibration. However, no significant differences were found in their abilities to observe errors in probe sensitivity or experimental variation. Results from phase two indicated improvement in graph scaling, probe sensitivity, and in experimental variation while no significant differences were found for probe setup or calibration.

Overall, Nachmias and Linn report that students were better able to critically evaluate graphs after being taught a semester-long curriculum via MBLs. They also feel that MBLs offer better views of science laboratories since they allow students to take part in experiences "...as research scientists do, seeking to understand the complex and unknown factors that influence observed events" (p. 504).

Linn, Layman, and Nachmias (1987) suggest that a chain of four links including graph features, graph templates, graph design skills, and graph problem solving skills is essential in order for students to fully understand and use graphs. They tested part of this "chain" through an 18 week physical science course with eighth grade students.

One group of students did the course in the fall with an MBL curriculum, while another group did it in the spring without MBLs and acted as the control group. The students wrote pre- and posttests that included items on graph features, temperature templates, and motion templates. Results showed that students using the MBL curriculum made significant progress in all three areas. The authors conclude that "...a microcomputer-based laboratory is effective in teaching students about graphing" (p. 252) and they suggest that the real-time aspects of MBLs may be acting as a "memory aid".

Linn and Songer (1991) suggest that the real-time graphing feature of MBLs "...supports the active, constructing nature of the learner" (p. 889). They feel that the real-time data gathering allows students to spend much needed time to repeat their experiments and also "provides memory support and frees the student to concentrate on integrating ideas" (p. 889).

Linn, Songer, Lewis, and Stern (1993) contend that students gain their scientific understandings through a sequence involving "action knowledge", "intuitive conceptions", and "scientific principles". The authors define action knowledge as knowledge that students have as a result of their experiences in life and say that students gain intuitive conceptions when they combine action knowledge with observations in order to make predictions. They refer to scientific principles as the abstract general rules that students acquire mainly through schooling.

Linn et al. believe that their Computer As a Lab Partner (CLP) curriculum, which combines real-time MBL activities and simulation type investigations, has played a key role along the action knowledge, intuitive conception, scientific principle continuum and has allowed students to foster their scientific understandings involving thermodynamics. However, they say that MBLs were not essential to the program and state:

> It becomes more and more clear that technology rarely teaches *thinking* but commonly improves *efficiency*. It frees students to think about scientific events. Specifically, real-time data collection frees students to think about their experiments. It is up to the curriculum developers to encourage knowledge integration (p.31)

Mcfarlane, Friedler, Warwick, and Chaplain (1995) describe a study in which four classes of seven and eight year olds studied the measurement of temperature and the recording of cooling graphs. Two classes (the experimental group) used MBL equipment and software for data acquisition and graphing. They were asked to predict what would happen when temperature probes were placed in different media and what could be done to make a graph take on particular features (i.e. make a line go up, down, go highest or lowest). The authors say "This gave a concrete introduction to the link between the events which occurred and the representation of those events in a line graph" (p. 465).

The students then carried out investigations involving the insulation properties of different materials. They filled bottles with equal amounts of water, wrapped them in different insulators, and then placed the temperature probes in the bottles. While the bottles cooled, the students made predictions on what the graphs would look like and also what materials would be the best insulators. The other two classes (the control group) performed the same activities using thermometers and paper-and-pencil graphing techniques.

The authors used pre- and posttest comparisons on both groups and concluded that the experimental group outperformed the control group in the reading and understanding of temperature/time graphs as well as in making predictions and sketching graphs of particular situations. The authors say that MBL techniques are "...manageable within the average primary classroom, given a degree of external support, but that to do so has very positive learning outcomes which are not achievable in other ways" (p. 478).

Stein, Nachmias, and Friedler (1990) report on an MBL study where eighth graders in four classes took part in a semester-length course on the topics of heat and temperature. Initially, all students experienced both MBL and non-MBL (traditional) laboratory exercises and then later in the course, each class was split into two groups (MBL and non-MBL) for a single experiment where they heated particular volumes of alcohol. The MBL groups recorded temperature with the computer and watched as their data was graphed in real-time on the computer screen in front of them. The non-MBL groups took measurements with a mercury thermometer every thirty seconds and then later graphed their results manually. Results of this study show that the MBL groups had less set-up time and more time "on-task" than the non-MBL groups. As well, the graphs produced by the computer for the MBL groups were better than those graphed manually by the non-MBL groups. Both groups came to valid conclusions from their graphs but, overall, students preferred using the MBL technique.

Svec, Boone, and Olmer (1995) discuss a project where MBLs were introduced into a physical science course for pre-service elementary teachers at Indiana University. Students used their own body movements, the motion of a toy car on a ramp, and the motion of a bouncing ball, to produce real-time graphs of distance, velocity, and acceleration during a three week motion unit. The students were given pre- and posttests that included a mixture of distance-time, velocity-time, and acceleration-time graphs.

Results on distance-time items (given only in the pretest) indicated that students were comfortable with distance-time graphs prior to their work with the MBLs. In terms of velocity-time graphs, students showed an improvement on posttest responses versus pretest responses. However, no improvement was shown in performance (pre-posttest) on the 3 items that linked a distance-time graph with possible velocity-time graphs.

Students displayed an overall improvement on test items involving acceleration-time graphs (less than 10% of students indicated correct responses on the pretest items, while 38% of students responded correctly to these items on the posttest). Svec, Boone, and Olmer suggest that the MBL activities improved the students' understandings of the motion topics covered in the 3-week unit and say that the "quick" real-time data and graphing capabilities of the MBL equipment opened the door to a variety of exciting activities.

MBLs As New Tools Of Science for Concept Development and Experimentation

Thornton (1985) and Thornton (1987a) report on the use of MBL units in five sixth grade classrooms in the Boston area where a motion unit was used for one full week for a 50 minute period per day. Thornton says that students quickly learned how to use the computer and MBL equipment and experimented freely using the motion of their bodies and the motion of toy cars rolling up and down an incline to produce real-time graphs. His preliminary conclusion is the "MBL motion unit can be an effective means of teaching middle school students to understand motion and graphing" (1987a, p.234).

Thornton (1985), Thornton (1987a), and Thornton (1987b) also describe MBL use in two physics courses for non-majors at Tufts University in Boston where students used MBL equipment and the motion of their bodies to produce distance-time and velocity-time graphs. Results indicate that students were comfortable with the equipment and software and had few problems in completing the laboratory exercises. Peer interaction and discussions, completed lab sheets, homework, and students verbal answers to questions indicate that students had a high level of understanding with respect to the motion concepts.

Thornton and Sokoloff (1990) report on the "Tools For Scientific Learning" project at Tufts University involving MBLs which had been extended from previous studies (Thornton (1985), (1987a), (1987b)) to include physics students from several colleges and universities. The authors say in the past three years, over 1500 students have been pre- and posttested and interviewed in order to examine the effect that MBLs have had on their understanding of kinematics topics.

Overall results indicate that "...there is strong evidence for significantly improved learning and retention by students who used MBL materials, compared to those taught in lecture..."(p. 862). Thornton (1985, 1987a, 1987b, 1990) suggests several pedagogical advantages of MBLs including:

1) MBL tools enhance student learning by extending the range of student investigations and allow students the opportunity to explore and quantify the physical world using sensors not commonly available to students.
2) MBL tools reduce the drudgery of data collection and can encourage "critical thinking".
3) MBLs provide for immediate feedback which may make the abstract more concrete.

4) MBLs may offer a means of teaching graphing concepts.

5) MBLs promote peer collaboration and encourages learning.

6) MBL tools are usable by the novice.

Joanne Stein (1987) reports on a study involving a teacher and his eighth grade students who used MBLs in their physical science classes. She says that the teacher enjoyed working with the MBL style labs, though he did note that it took a lot of preparation time to conduct MBL activities effectively. Stein also reports that the teachers time in the labs was split between helping the students with the MBL equipment and teaching science concepts, and though the teacher had few problems with the equipment, when a problem did arise, it required considerable time to fix.

In terms of the students, Stein says that they spent a great deal of time on task when working with the MBL equipment and even students with learning difficulties persevered and carried out the MBL activities. However, she notes that much of this time was spent focusing on empirical lab procedures and little on the cognitive aspects of the concepts being studied. Stein explains that students seemed comfortable with the graphic display offered by the MBLs and that peer consultation and interaction allowed students to successfully remedy many of the problems they encountered. Overall, Stein thinks that the curriculum presented in an MBL manner provided students with a better understanding of heat and temperature concepts, though she does point out that MBLs must be implemented carefully.

Svec (1995) reports on a study that involved students in two undergraduate physics courses. One class served as the control group and used traditional motion laboratories through the duration of their course, while the second class served as the treatment group and utilized MBLs to do experiments in their course.

The results on pre- and posttest Graphing Interpretation Skills Tests (GISTs) indicate that MBLs improved students' graphing interpretation skills in the treatment group while no improvement in graph interpretation was shown for students in the control group. Similarly, pre- and posttest results on Motion Content Tests (MCTs) indicated that MBLs improved students' ability to interpret motion graphs in the treatment group, while only slight improvements in interpreting motion graphs were made by the control group. Results from the non-graphing portion of the MCTs showed that MBLs allowed students in the treatment group to improve on their conceptual understanding of motion while again, students in the control group showed only slight improvements. Svec says "...analysis of results indicate the superiority of MBL activities over traditional methods for instruction on motion. Incorporation of MBL activities is, therefore, recommended for instruction"(p .22).

Friedler, Nachmias, and Songer (1989) studied the learning of scientific reasoning skills by 250 eighth graders as they took part in a sixteen week MBL module. The goals of the first three weeks were to introduce students to planning experiments, stating hypotheses, controlling variables, and making predictions and observations. In the remaining thirteen weeks, students used MBLs in heat and temperature experiments where data was collected and graphed in real-time.

Classroom evaluation (including observations and assessments of worksheet activities, tests, and student interviews) indicated that students learned to critically evaluate computer generated data. As well, the authors note that :

> Our evaluation showed an improvement in student abilities to plan, to control variables while designing an experiment, to make careful observations, to distinguish between observations and inferences, to make detailed predictions, and to justify them on the basis of their previous experiments (p. 65).

Friedler, Nachmias, and Linn (1990) looked in detail at 110 of the students involved in the report by Friedler, Nachmias, and Songer (1989) as they were split into either a prediction group or an observation group. Results showed that students in the observation group learned how to make detailed observations about their experiments and, in addition, learned how to exclude inferences from these observations. Students in the prediction group not only learned how to make detailed predictions, but were also able to justify the reasoning for these predictions. The researchers say that the successful instruction of prediction and observation skills was a very important result of their study and that " MBL constitutes a new class of technology which allows students to use the computer as research scientists do: to collect, record, and manipulate data" (p. 176).

Settlage (1995) describes a qualitative study where a teacher used an eight week MBL unit with her third graders to study the behaviour of light. The students used five MBL setups with light probes to investigate the "bouncing" and "blocking" of light. In one activity, the students shined a flashlight into a hole in a box and used the light probe to measure the amount of light coming out of several other openings. They used their results to guess the position of a mirror in the box. Another activity had the students measuring light as it was passed through different opaque materials. In the last couple of weeks, the students worked on their own projects and presented results to the class. Settlage feels that the "...children developed an increasingly sophisticated understanding of graphs and how they relate to light" (p. 547). "Having frequent access to the graph-making potential of the MBLs supported the children's understanding of graphs" (p. 547). Settlage also believes that the MBLs helped the children in their understanding of light and science learning "...especially in the form of increased facility with scientific inquiry" (p. 548).

Trumper (1997) examined the effects that MBLs had on the performance of physics students in analyzing graphs of their kinematics experiments. One group of students studied kinematics concepts, including graphing, for 5 ninety minute periods the "conventional way" and 5 ninety minute periods using MBL techniques. A second group did identical activities but in reverse order (i.e. first MBL and then conventional). A third group acted as the control sample and they spent the full duration studying the material via the "conventional" manner (learning kinematics concepts, graphing, and doing traditional physics labs).

The MBL activities had students moving in front of the V-scope. This movement simultaneously produced graphs on the computer screen in front of them. Stumper had students in the three groups do pre and posttest questionaries and found that all students improved in their ability to use and interpret graphs. He also reports that in comparing the results of posttests alone, the MBL students outperformed the control group (statistically significant difference at an 0.01 level). He feels that "The learning provides a real-time link between a concrete experiment and the symbolic representation of that experience" (p. 107) and concludes that the "V-scope kinematics laboratory gives students the opportunity to experience the excitement and process of science" (p. 109).

Berg and Smith (1994) were concerned with the use of multiple-choice questioning in MBL studies as a valid method of assessing the graphing skills and capabilities of students. They contend that much of the MBL research completed to date does not allow students to freely respond to questions and, thus, conclusions relating to the positive affects that MBLs have may be invalid on graphing abilities. "Some of our beliefs about graphing capabilities and the effects of MBL on graphing have been derived from subjects' responses that were perhaps more of an effect of the instrument than a measure of the subjects' graphing abilities" (p.552).

Nakhleh and Krajcik (1993) investigated students' actions, thoughts, and verbal commentary during acid-base titrations. Three types of technologies were used with three groups of students. The first group used a chemical pH indicator to detect changes in pH, the second group utilized pH meters, and the third group worked with MBL setups. All groups graphed data pertaining to their titrations and discussed the results with the researchers. Nakhleh and Krajcik conclude that the microcomputer technology was effective for a couple of reasons. First, it allowed for the real-time graphing of data as the titration proceeded. This not only acted as a memory aid for the students, but also allowed them to focus their attention on the evolving graph. Secondly, the MBL technology gave students ample time "...to reflect upon, predict about, and speculate upon the phenomena they were observing" (p.1167).

Nakhleh and Krajcik (1994) investigated students' understanding of acid, base, and pH concepts before, during, and after they performed acid-base titrations using three different technologies. One group of students performed the titrations using a chemical pH indicator, another group used a pH meter, and a third group used a microcomputer to collect data. All students were interviewed before and after the titrations and concept maps for each student were constructed and scored based on these interviews.

The investigators report that the MBL students had the greatest change in understanding from initial to final concept maps and felt that "...students using MBL activities constructed more detailed and more integrated chemical concepts, which may have resulted in more meaningful understandings. The final maps of the MBL group showed greater integration and elaboration of concepts" (p.1092). Though Nakhleh and Krajcik conclude that MBLs allow for a better understanding of acid and base concepts, they indicate that more research needs to be done in this area including the notion that MBLs may function as a "memory" device for students.

Teacher and Student Attitude Toward MBLs

Heck (1990) developed and administered a Likert-style questionnaire to fifty secondary science teachers in Hawaii who had previously taken part in an MBL in-service program. Of the 43 teachers who responded to the survey, 37 indicated they had used MBLs since the in-service, however, MBL exercises comprised only a small percentage of the total number of labs done with students (95% of teachers used them in 1/4 or less of the total time spent on labs). With reference to planning, teachers agreed that MBL materials are adaptable to the science curriculum and have enhanced it. However, teachers noted that it took considerable preparation time to prepare lessons involving MBL techniques.

In terms of student learning and activities, teachers believed that MBLs have impacted positively on students' attitudes toward completing lab assignments and have made student learning of required material more effective than "traditional" labs. Also, teachers report that MBLs have positively affected students' abilities to compile and draw conclusions from data and have impacted positively on students' abilities to use the computer for scientific inquiry.

With respect to materials, teachers surveyed said they received a lot of support from their science/computer resource centre and commented that the MBL software packages were easy to use with the students. However, they indicated that they lacked an adequate amount of MBL hardware in order to use MBLs to their full potential and were of the opinion that to improve the use of MBL labs, they needed more hardware, software, and training.

Heck says that:

> It appears clear that teachers in this training program reacted favourably about the potential benefits of MBL techniques in enhancing laboratory experiences for students and in becoming a viable part of the secondary science curriculum (p.81).

Lehman and Campbell (1991) discuss a project where MBLs were used by teachers and students in six high schools in Indiana. At its inception, the project was to focus on student and teacher attitude toward MBLs, classroom observations of MBLs, and the graphing performance of students using MBLs.

Teachers attitudes toward MBL use were to be assessed by interviews and a Likert-type questionnaire developed by the authors, while students attitudes toward MBLs were to be determined by a questionnaire only. In addition, students attitudes' toward computers were to be assessed via a Likert-type survey and their graphing skills assessed by the Test of Graphing in Science (TOGS).

Results on student instruments are limited because at the time this article was written, data from only one high school had been received. This data showed no evidence of MBL use on either student attitude toward computers or on student graphing skills. However, the researchers say that students indicated overall positive attitudes toward MBL activities and "Those who have been less positive, for the most part, seem to be students who have had relatively little exposure to the MBL, either through the lack of opportunity or lack of interest" (p. 12).

The authors say that classroom visits and teacher comments to date indicate that teachers have an overall positive and enthusiastic attitude toward MBLs. They also note that teachers recognize a number of advantages of MBL technology including real-time graphing, data manipulation, ease of use, sturdiness, and accuracy.

In an article by Powers and Salamon (1988) the authors discuss "Project Interface" that involved the introduction of computers into the science curriculum at a high school in Missouri where students were assigned to either a experimental group (MBL group) or a control group (non-MBL). The goals of the project were as follows:

1. After using computer interface modules, students will:

   a) exhibit a more positive attitude toward science.

   b) demonstrate improved cognitive skills.

   c) increase their computer literacy.

2. After using MBLs, teachers will improve their computer literacy and knowledge.

Student assessment instruments used included the "Scientific Attitude Inventory" (for assessing attitudes toward science) and teacher designed tests (for assessing science skills and computer literacy). Teacher data was based on self-assessments given at the conclusion of the project.

Results on student attitude toward science showed that 54% of the experimental group students and 46% of control group students increased their scores on the pre- and posttest Scientific Attitude Inventory. In terms of student cognitive skills, the authors failed to give experimental group data but did state that the experimental group showed a greater increase on pre- posttest scores than the control group did on the assessment instruments designed by the teachers. Results on student computer literacy revealed that 48% of the experimental group students and 19% of control group students increased their scores on pre-posttest computer literacy instruments.

The authors say the goal involving teacher computer literacy and knowledge was "fully achieved" and that teachers "...felt that their expertise in science and computer interfacing technology had increased dramatically and that personal barriers regarding computer use were overcome" (p. 92).

Powers and Salamon (1988) mention that results on an informal survey showed that 89% of students liked using the MBL format and that 82% of them preferred using MBLs versus "regular" type labs. In addition, 85% of students said they learned more using computers in their activities than if they had not used them.

Teacher and student attitudes toward MBLs were discussed in an ethnographic study done by Kim (1989). The teacher involved in this study "...decided to use MBLs for both personal and professional reasons: the desire to develop professionally, to learn the newest tool of the trade, and most importantly, to do his job better" (p. 116). He thought that MBLs provided not only an interesting way of approaching labs, but also a means to help students observe exactly how computers affect them and the rest of society. The teacher also expressed the opinion that with MBLs, he could do many things that could not be attempted before. He said that "with MBLs, he could concentrate on the 'real meat of science' " (p.117). Kim (1989) goes on to say that the teacher felt that MBLs provided him with a way of rekindling "...his waning enthusiasm about teaching" (p. 117).

Kim (1989) also looked at students attitudes toward MBLs and says that there were three major areas of findings. First, students expressed the opinion that they learned better because MBLs were "more fun". The students said that they enjoyed the MBLs because they could investigate topics that were interesting to them. For example, Kim (1989) found that "One of the fun and interesting discussions was how to keep Coke cool longer at the beach on a hot summer day (would one wrap it with aluminum foil or wool cloth?)" (p. 138).

Secondly, Kim found that MBLs affected students self-esteem. "Their self-image improved, they became to feel more independent, they work like 'real scientists', feeling more responsible for their own learning" (p. 140).

Finally, Kim found that students collaborated more when using the MBLs. "Interactions and dialogues were more on the task rather than non-school related topics" (p. 143). In addition, the students shared their data and this "...encouraged co-operative remediation of problems, with students forming into consulting groups of increasing size according to the difficulty of the problem at hand" (p. 143).

John R. Amend and his colleagues at Montana State University (MSU) have published several articles on MBL use. Amend, Furstenau, Reed et al. (1990) focus on the technical details of their MBL devices developed at MSU. Amend, Briggs, Furstenau et al.

(1989) address the technical aspect of their MBL devices and discuss the in-servicing of 76 high school teachers on the use of MBL techniques used at MSU.

Amend, Furstenau, and Tucker (1990) again review the details of their MBL devices, but in addition, report on how students in a test-section of a chemistry course were required to program an interfacing device on their own in order to complete a prescribed experiment. Results showed that all students configured the device properly and were able to proceed and complete the experimental work required. The students commented on the usefulness of the computer device in gathering and analyzing data and, as well, said that the project had challenged them and made them more comfortable around computers.

In Amend and Furstenau (1992), the authors first discuss the philosophy behind the introductory chemistry course Chem 125 offered at MSU where up to 1200 students per quarter participate in MBL style techniques. They then report on a survey conducted on 190 Chem 125 students to assess students' attitudes toward the MBL procedures.

Results revealed that 75% of students felt the MBL style projects used in the course were "good" or "excellent" ideas. Almost one-half (49%) of students said the computers were "very useful" and about 30% commented that they were "useful".

Fifty-seven percent of students said they were now "comfortable" with computers and approximately 90% of students said the computers were easy to use. Amend and Furstenau (1992) conclude that students "...overwhelmingly find the computer useful for learning chemistry in the laboratory..."(p. 114) and say the laboratories used at MSU "...are an integral part of the chemistry labs for science and non-science majors alike"...(p.114).

Summary of Research Literature

This chapter reviewed the research literature on microcomputer-based laboratories. The three main areas covered were MBLs and graphing, MBLs as tools of science for the development of concepts and scientific experimentation, and teacher and student attitude toward MBLs.

The ability to construct, interpret, and understand graphs is important for students in analyzing scientific data. Many of the articles reviewed discuss studies which have shown that MBLs do improve students' skills in these areas. In particular, the real-time graphing capabilities of MBLs may be the key attribute since it allows students to see a graph produced on a computer screen as the experiment progresses. Some researchers believe that this may provide a link between the "abstract" and "concrete".

A number of studies reviewed provide evidence that MBLs offer an effective means of teaching and developing science concepts. Examples are given in the areas of kinematics (motion), thermodynamics (heat, temperature, energy), chemistry (pH/acids and bases), and light (reflection and intensity). As well, the literature suggests that MBLs may foster students' experimentation abilities such as making better predictions and observations, critically evaluating and interpreting data, planning experiments, controlling variables, and developing reasoning and scientific inquiry skills.

Results of the literature review suggest that overall teacher and student attitude toward MBLs is positive. Teachers and students alike enjoy working with MBL techniques and believe that MBLs offer a wide range of possibilities within their science labs.

CHAPTER 3

METHODOLOGY

This study deals with determining the attitudes that teachers and students have toward Microcomputer-Based Laboratories (MBLs) in the province of Newfoundland and Labrador. The following section contains descriptions of the instruments used, the samples, the data collection process, and a discussion on the validity and reliability of the instruments.

Teacher Questionnaire Design

A study by Heck (1990) assessed the attitudes that secondary science teachers in Hawaii had toward MBLs. After carefully examining this article, it was decided that what Heck did was similar in nature to what this researcher wanted to do to determine the attitudes that teachers and students of this province had toward MBLs. Therefore, contact was made with Heck and a copy of the teacher questionnaire used in his study, along with permission to adapt it, was obtained. After a review of the literature on MBLs, and using Hecks questionnaire as a rough guide, a teacher questionnaire was designed for this study which contained three sections.

Section A consisted of seven multiple-choice items and was used to determine to what extent teachers and students had used MBLs. Section B was composed of thirty-four statements that teachers responded to by using a five point Likert scale consisting of the responses : SD - Strongly Disagree; D - Disagree; U - Undecided; A - Agree; SA - Strongly

Agree. This part of the instrument was used to gain an understanding of teachers' attitudes toward MBLs. Section C was used to obtain personal information about the teachers. Such information will be used when discussing the overall results of the questionnaire.

Student Questionnaire Design

A student questionnaire, similar to the teacher questionnaire, was designed for this study by the author and it contained two sections. Section A was used to obtain some personal information from the students. Section B was composed of thirty statements that students responded to using a five point Likert scale consisting of the responses: SD - Strongly Disagree; D - Disagree; U - Undecided; A - Agree; SA - Strongly Agree. Section B was used to determine students' attitudes toward MBLs.

The Samples

In 1991 - 1992, a series of week-long physics institutes were given in five areas of the province of Newfoundland and Labrador: Deer Lake, Gander, Clarenville, St. John's, and Happy Valley-Goose Bay. The institutes focused on computer interfacing equipment (both the Vernier and Super Champ systems) and MBL laboratory techniques. Though the emphasis was on using MBLs in the physics courses taught in the province, demonstrations and experiments relating MBLs to other science courses (i.e. biology, chemistry) were part of the sessions. Teachers from approximately one hundred schools from all Boards in the province attended these institutes.

The researcher in discussion with his advisor, several science coordinators of school boards in the province, and a number of teachers known to be versed in MBL usage, decided that the teachers who attended the physics institutes would make up the majority of teachers in the province who may be using MBLs with their students. Therefore, the teacher sample for this study was obtained from this group of teachers. The student sample for this study consisted of students of the teachers who took part in the institutes in 1991 - 1992.

Data Collection

Before collecting data, a thesis proposal outlining the research was submitted to the Ethics Review Committee of the Faculty of Education at Memorial University of Newfoundland. It included a copy of the questionnaires along with samples of appropriate consent forms. The Ethics Review Committee passed the proposal in February of 1994.

Superintendents of all school boards in the province were sent letters asking permission to administer questionnaires to teachers and students within their boards, and within a couple of weeks, all superintendents had responded positively to the request.
An attempt was then made to contact all teachers who had participated in the physics institutes of 1991-1992.

One hundred and two of the one hundred and fifteen teachers who took part in the institutes were located. Thirty four teachers said they had not used MBLs with their students and, therefore, were not considered for this study. Sixty eight of the one hundred and two indicated they were using MBLs and agreed to take part in the study. Each of these teachers were asked to randomly select one or two of their students to complete the student instrument. A teacher questionnaire along with two student questionnaires and consent forms were sent to the sixty eight teachers who agreed to take part in the study.

A province-wide teachers strike (spring of 1994) occurred a few weeks after the instruments were initially sent to teachers. In anticipation of a poor return rate, the researcher contacted all teachers who had agreed to participate in the study and again asked for their support in returning questionnaires.

Validity of Instruments (opinion of judges)

After initially constructing the questionnaires for this study, the author met with two science education professors at Memorial University of Newfoundland. They reviewed the instruments making suggestions for improvements in the structure and wording. The questionnaires were re-worked and the suggestions implemented.

The researcher then met individually with four teachers who taught high school physics and had used MBLs with their students. Two of these teachers were teaching physics via the distance education program in the province where the majority of labs completed by physics students are conducted by MBL methods. The teachers provided the researcher with numerous comments and suggestions regarding the content and wording of the questionnaires. Two of the teachers also chose several of their students to scrutinize the student instrument. Appropriate changes were made.

The author met again with the four teachers and they re-examined both the teacher and student surveys. All were of the opinion that the instruments were valid for the purposes of this research.

Reliability of Instruments

The education professors and physics teachers who reviewed the survey instruments were of the opinion that these instruments would produce reliable results. A Cronbach α (a measure of internal consistency) for both the teacher questionnaire and student questionnaire will be reported in Chapter 4.

CHAPTER 4

RESULTS

This section contains the results of the study and includes a general description of the samples, an indication of the reliability of the survey instruments, and a discussion on each of the research questions posed in Chapter 1. The scoring used in Tables 3 through 13 is based on the following: Strongly Agree - 5 points; Agree - 4 points; Undecided - 3 points; Disagree - 2 points; Strongly Disagree - 1 point. Negatively worded statements were recoded based on the following: Strongly Agree - 1 point; Agree - 2 points; Undecided - 3 points; Disagree - 4 points; Strongly Disagree - 5 points.

Description of Teacher Sample

Fifty-three of the sixty-eight teachers who were sent questionnaires responded to the survey. This corresponds to a 77.9% return rate. The fifteen teachers who did not return questionnaires were contacted by telephone and the majority cited the province-wide teachers strike in May (1994) and the associated "end-of-school-year" duties and pressures as the reasons they would not be responding to the surveys.

Fifty of the fifty-three teachers who responded were males (94.3%) and three were female (5.7%). With respect to age, 39.6% were between 25 - 35 years, 41.5% between 36 - 45 years, and 18.9% were greater than 45 years of age. In terms of university education, 86.9% of respondents hold B. Sc. and B. Ed. degrees, 9.4% have B. A. and B. Ed. degrees, 15.1% have both a B. Sc. and B. A. degree (along with their education degree), and 28.3% have some type of Masters degree (M.Ed./ M.A./ M.Sc.).

Table 1 below gives the breakdown of area of major within the degrees held by teachers.

Table 1

Area of Major

Discipline	*Percent of teachers (%)*
Mathematics	18.9
Physics	22.6
Chemistry	3.8
Biology	22.6
Earth Science	15.1
Joint Math/Physics	5.7
Non-Science	11.3

The teaching experience of the teachers surveyed is presented in Table 2

Table 2

Teaching Experience

Number of years	*% of teachers*
1 - 5	15.1
6 - 10	19.0
11 - 15	7.6
16 - 20	26.3
21 - 25	22.5
26 - 30	9.5

The majority of teachers surveyed (46 of 53) indicated that their teaching responsibilities were in the mathematics and science areas. 39.6% of teachers indicated that they had no formal university computer credits while 41.6% said they had one or two computer credits. 17.1% of them had between 3 and 6 computer credits. One teacher had 15 computer courses completed at the university level. 24.6% of the teachers rated their computer knowledge as low, 52.8% indicated an "average" computer knowledge, and 22.6% of them said they had an "above average" computer knowledge.

Description of Student Sample

Since 68 teacher surveys were sent out, and every teacher was asked to choose two students to complete the student survey, there were a possible 136 student surveys that could have been returned. However, only 59 student instruments were sent by teachers. This corresponds to a 43.4% return rate. The overall low number of student surveys returned was unfortunate and this may weaken the student data.

Of the fifty-nine student surveys returned, forty-six were sent with teacher surveys that were completed before the teachers strike and sixteen were sent in after the strike. This indicates that many of the teachers who responded after the strike did not return student questionnaires.

Thirty-six (61%) of the students were male, twenty-three (39%) were female, 10.2% of the them were enrolled in Level I, 44.1% were in Level II, and 45.7% were in Level III. 17% of students considered themselves as having a "low" knowledge of computers, 64.4% said they had an "average" knowledge of computers, and the remaining 18.6% thought that their computer knowledge was "above" average. Forty (67.8%) of the students felt that they liked science "about average", eighteen of them (30.5%) said they liked science "more than average", and only one student concluded that he/she liked science "less than average".

Reliability of Teacher Instrument

A reliability analysis to determine the Cronbach Alpha (α), a measure of internal consistency, was completed for the thirty-four Likert-type statements on the teacher instrument. This was calculated to be 0.90 indicating a high degree of reliability.

Reliability of Student Instrument

A Cronbach Alpha (α) was also determined for the thirty Likert-type statements on the student instrument. This was calculated to be 0.86, again indicating a high degree of reliability.

Research Questions

To what extent have teachers and students used MBLs?

Approximately 19% of teachers surveyed indicated that students themselves used MBL equipment and software to collect and analyze data while 7.5% of the teachers said they used MBL equipment in demonstrations with their classes. Just over 64% of the teachers remarked that MBL procedures were used both by students (to collect and analyze data) and themselves (in demonstrations with their classes). A small percentage of teachers (7.6%) said they had used MBLs, but did not indicate in what manner. One teacher did not respond to the question.

In terms of the number of computers accessible for use in labs, 54.7% of teachers said that only one computer was available, 18.9% said that two computers were available, 24.5% said that three were available, and one teacher indicated that he had none readily available for use. In relation to MBL equipment (computer interfacing units), 45.3% of teachers indicated that they had one set-up, 18.9% had two, 5.7% had three, and 28.8% had more than three.

For the question "How often do you have physics labs?", 5.7% of teachers said they had them every week, 37.7% said every two weeks, 30.2% said every three weeks, and 22.6% had varying answers like "once a month", "whenever I get the chance", etc,. Two teachers did not respond to this question.

Keeping in mind their responses as to how often physics labs are done, 9.4% of teachers said they used MBL techniques in their labs 75% - 100% of the time, 7.5% said they used MBLs in their labs 50% - 74% of the time, 20.8% said they used MBLs in their labs 25% - 49% of the time, while 58.5% said they used MBL techniques in their labs 0% - 24% of the time. Two teachers did not answer the question.

About one-half of the fifty-three teachers surveyed indicated they had used MBLs in other courses (besides physics). Thirteen had used them in chemistry courses, five in biology, two in earth science, four in junior high science, three in physical science, and three in computer technology. As well, 28.8% of students surveyed said they had used MBLs in other courses (besides physics).

When conducting MBL labs, 22.6% of teachers said that students performed them in groups of two, 22.6% of teachers said that students performed them in groups of three, 26.4% of teachers said that students performed them in groups of four, 20.8% of teachers said that students performed them in groups of greater than 4, and a small percentage of teachers did not indicate how students were grouped.

What are teacher and student attitudes toward MBL equipment and software?

The statements used to determine teacher attitude toward MBL equipment and software are summarized in Table 3. Teachers feel that MBL software is easy to use ($\bar{x}$=3.98) and indicate their students are able to use it on their own ($\bar{x}$=3.72). Teachers also feel that MBL equipment is not difficult to setup ($\bar{x}$=3.81) and while 51% of them noted that they do not run into "technical" difficulties ($\bar{x}$=3.27), about 38% said that they did. Fifty-one percent of teachers found the printed material that accompanies the MBL equipment easy to follow, while 20% of their colleagues had the opposing view.

Table 3
Teacher attitude of MBLs re: equipment and software

Statement	(N)	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	Mean	S. D.
		Amount of agreement(%)					(* recoded)	
The computer software associated with MBLs is easy to use.	53	24.5	58.5	7.5	9.4	0	3.98	0.84
Students are able to use the MBL computer software on their own.	53	15.1	58.5	11.3	13.2	1.9	3.72	0.95
The printed material that comes with the MBL equipment (i.e. manuals or guides that accompany the Vernier and/or Super-Champ systems) is easy to follow and helpful.	53	5.7	45.3	28.3	18.9	1.9	3.34	0.92
I find it difficult to set-up the MBL equipment for any given experiment.	53	1.9	17.0	13.2	47.2	20.8	2.32 3.81*	1.05 0.96*
I feel somewhat intimidated by the MBL equipment and software.	53	0	15.1	5.7	34.0	45.3	1.91 4.19*	1.06 1.02*
I often run into "technical" difficulties when using MBL techniques.	53	3.8	34.0	11.3	41.5	9.4	2.81 3.27*	1.13 1.12*

The statements used to determine student attitude toward MBL equipment and software are detailed in Table 4. Students find the MBL software easy to use ($\bar{x}$=4.00) and can easily "run" a particular lab set-up several times once the equipment is in place ($\bar{x}$=4.22). Over 80% of them say that the MBL equipment is not hard to use ($\bar{x}$=3.91) and 86% believe that data is easily printed once gathered ($\bar{x}$=4.25). Sixty-one percent of students suggest that they do not run into problems when using MBL techniques, while almost 55% say they can set-up MBL equipment on their own

Do teachers and students believe that MBL techniques enhance student learning?

Teachers and students responded to several statements concerning MBL techniques and student learning. The teacher data is given in Table 5 and the student data is presented in Table 6.

The teacher data suggests that MBLs have helped students interpret and analyze data ($\bar{x}$=3.89) and offer an effective means of teaching graphing concepts ($\bar{x}$=3.89). Similarly, students feel that MBLs have assisted in their understanding of graphing ($\bar{x}$=3.62) and in examining data ($\bar{x}$=4.07). Both teachers and students suggest that MBLs allow time for "critical thinking" ($\bar{x}$=3.71 and $\bar{x}$=4.02 respectively) and for studying concepts via different approaches within a lab session ($\bar{x}$=4.02 and $\bar{x}$=4.24).

Table 4
Student attitude of MBLs re: equipment and software

Statement	(N)	Amount of agreement(%)						
		Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	Mean	S. D.
							(* recoded)	
The computer program (software) associated with the MBLs is easy to use.	59	18.6	66.1	11.9	3.4	0	4.00	0.67
Once the equipment for a particular lab is set-up, I can easily "run" the experiment several times.	59	35.6	52.5	10.2	1.7	0	4.22	0.70
I often run into problems when using the MBL equipment and software.	57	0	20.3	15.3	55.9	5.1	2.53 3.47*	0.89 0.89*
I would not be able to set-up MBL equipment by myself.	59	3.4	25.4	16.9	39.0	15.3	2.63 3.39*	1.13 1.15*
I can easily print data (tables and graphs) after the data has been gathered by the MBL equipment.	59	42.4	44.1	10.2	3.4	0	4.25	0.78
MBL equipment is hard to use	59	1.7	5.1	11.9	64.4	16.9	2.10 3.91*	0.80 0.81*

Table 5
Teacher attitude of MBLs re: affecting the learning that takes place in the lab

Statement	(N)	Amount of agreement(%) Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	Mean	S. D.
							(* recoded)	
MBLs have helped students in interpreting and drawing conclusions from data.	51	15.1	47.2	30.2	3.8	0	3.76	0.76
MBL tools offer an effective means of teaching graphing concepts.	53	17.0	60.4	17.0	5.7	0	3.89	0.75
Because MBLs reduce the time needed for data collection, students are able to "think critically" about what they are doing.	51	18.9	37.7	34.0	3.8	1.9	3.71	0.90
MBLs are no better than the "traditional" (non-MBL) labs when it comes to students' understanding of concepts.	53	1.9	17.0	28.3	35.8	17.0	2.51 3.54*	1.03 1.01*
Since MBL equipment can process data quickly, more cases or situations involving a concept can be analyzed in a lab session. i.e. more time for trying different approaches or different "angles".	53	22.6	62.3	9.4	5.7	0	4.02	0.75
I don't believe that students' science learning has benefitted from the incorporation of MBLs.	52	0	1.9	9.4	56.6	30.2	1.83 4.21*	0.68 0.68*

Table 6
Student attitude of MBLs re: affecting the learning that takes place in the lab

Statement		Amount of agreement(%)						
	(N)	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	Mean	S. D.
							(* recoded)	
MBLs have helped me in interpreting and drawing conclusions from data.	59	25.4	57.6	15.3	1.7	0	4.07	0.69
MBLs haven't increased my graphing capabilities.	59	3.4	13.6	22.0	42.4	18.6	2.41 3.62*	1.05 1.04*
Because MBLs reduce the time needed for data collection, I am better able to concentrate on what's "going on" in an experiment.	59	20.3	67.8	5.1	6.8	0	4.02	0.73
MBLs are no better than the "traditional" (non-MBL) labs when it comes to the understanding of concepts.	58	6.8	10.2	23.7	37.3	20.3	2.45 3.55*	1.14 1.14*
Since MBL equipment can process data quickly, more cases or situations involving a concept can be analyzed in a lab session. i.e. more time for trying different approaches or different "angles".	58	32.2	57.6	8.5	0	0	4.24	0.60
MBL techniques have not enhanced the learning that takes place in our labs.	58	1.7	6.8	8.5	66.1	15.3	2.12 3.88*	0.82 0.82*

It appears that teachers and students believe that MBLs may be better than the traditional (non-MBL) labs in terms of understanding concepts ($\bar{x}$=3.54 and $\bar{x}$=3.55), however, 28.3% of teachers and 23.7% of students were undecided in this area. Overall, teachers ($\bar{x}$=4.21) and students ($\bar{x}$=3.88) agree that MBLs have positively affected the learning that goes on in the lab.

Do teachers and students believe that MBL techniques enhance their physics course(s)?

The teacher and student responses to statements concerning this question are given in Table 7 and Table 8 respectively. Both sets of respondents believe that MBLs offer advantages over non-MBL labs ($\bar{x}$=4.31 and $\bar{x}$=4.29). Teachers also think that students find MBLs enjoyable and stimulating ($\bar{x}$=4.00)) and have had a positive effect on lab assignments ($\bar{x}$=3.73). Students concur with teachers on these statements ($\bar{x}$=3.93 and $\bar{x}$=3.76).

Teachers suggest that students find MBLs more interesting than non-MBLs ($\bar{x}$=3.88) and students agree with this ($\bar{x}$=4.14). Teachers and students also agree that MBL technology is fun, motivating, and adds to the quality of their physics courses ($\bar{x}$=4.39 and $\bar{x}$=4.41). Finally, teachers and students share the opinion that MBLs enhance their physics courses (teachers $\bar{x}$=3.85 and students $\bar{x}$=4.26).

Table 7

Teacher attitude of MBLs re: enhancing their physics courses

Statement	(N)	Amount of agreement(%) Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	Mean	S. D.
							(* recoded)	
I don't see any advantages of using MBLs over the "traditional" (non-MBL) labs.	53	0	1.9	5.7	52.8	39.6	1.70 4.31*	0.67 0.66*
MBLs have had positive effects on students' attitudes toward doing laboratory assignments.	52	13.2	50.9	28.3	5.7	0	3.73	0.77
MBLs haven't enhanced my physics course(s).	51	3.8	15.1	5.7	43.4	28.3	2.20 3.85*	1.15 1.15*
Students find MBLs more interesting than "traditional" (non-MBL) laboratory sessions.	52	13.2	64.2	17.0	3.8	0	3.88	0.68
Using "modern" technology such as MBLs is fun, motivating, and adds to the quality of my physics course(s).	51	41.5	50.9	3.8	0	0	4.39	0.57
Students find MBLs enjoyable and stimulating.	52	18.9	60.4	18.9	0	0	4.00	0.63

Table 8

Student attitude of MBLs re: enhancing their physics courses.

Statement		Amount of agreement(%)						
	(N)	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	Mean	S. D.
							(* recoded)	
I don't see any advantage that MBLs have over the "traditional" (non-MBL) labs we have always done.	58	0	3.4	10.2	39.0	45.8	1.71 4.29*	0.79 0.79*
I find MBLs enjoyable and stimulating.	59	11.9	61.0	20.3	5.1	1.7	3.76	0.80
MBLs have had a positive effect on my attitude toward doing laboratory assignments.	59	11.9	71.2	15.3	1.7	0	3.93	0.58
I don't think that MBLs have enhanced our physics course(s).	58	1.7	0	6.8	52.5	37.3	1.74 4.26*	0.74 0.74*
MBLs are more interesting than "traditional" (non-MBL) laboratory sessions.	59	33.9	49.2	13.6	3.4	0	4.14	0.78
Using "modern" technology such as MBLs is fun, motivating, and adds to the quality of our physics course(s).	59	49.2	44.1	5.1	1.7	0	4.41	0.67

Do teachers and students believe that MBLs have affected student attitude toward science and computers?

The teacher data concerning this issue is summarized in Table 9 and the student data is given in Table 10. Teachers and students think that MBLs have made students more comfortable around computers ($\bar{x}$=3.90 & $\bar{x}$=3.77) and have increased students' levels of computer literacy ($\bar{x}$=3.98 & $\bar{x}$=3.90). The data also suggests that teachers and students believe MBLs have positively influenced students' views of computers ($\bar{x}$=3.67 & $\bar{x}$=3.47) and have had a positive effect on student interest toward science ($\bar{x}$=3.65 & $\bar{x}$=3.61).

Over 60% of teachers and approximately 40% of students share the opinion that MBLs allow students to feel more like "scientists", though, 32% of teachers and 42% of students are undecided in this category. Finally, it appears that teachers ($\bar{x}$=3.50) and students ($\bar{x}$=3.75) believe that students view MBLs as more "scientific" than the traditional (non-MBL) techniques.

Table 9
Teacher attitude of MBLs re: affecting students' attitudes toward science and computers.

Statement	(N)	Amount of agreement(%) Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	Mean	S. D.
							(* recoded)	
MBLs have increased students' levels of computer literacy.	51	24.5	47.2	22.6	1.9	0	3.98	0.76
MBLs haven't had a positive effect on students' views of computers.	52	3.8	13.2	15.1	47.2	18.9	2.35 3.67*	1.06 1.08*
MBLs make students feel more like scientists.	52	13.2	47.2	32.1	5.7	0	3.69	0.78
MBLs haven't changed students' levels of interest toward science.	51	0	13.2	26.4	39.6	17.0	2.37 3.65*	0.94 0.96*
Students don't view MBL techniques as any more "scientific" than the "traditional" (non-MBL) techniques they have used.	52	0	15.1	32.1	43.4	7.5	2.56 3.50*	0.85 0.85*
MBL experiences have made students feel more comfortable around computers.	52	13.2	50.9	32.1	1.9	0	3.77	0.70

Table 10
Student attitude of MBLs re: attitudes toward science and computers

Statement	(N)	Amount of agreement(%) Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	Mean	S. D.
							(* recoded)	
MBLs have increased my knowledge and understanding of computers.	59	28.8	42.4	18.6	10.2	0	3.90	0.94
MBLs have not changed my view of computers.	59	5.1	16.9	22.0	44.1	11.9	2.59 3.47*	1.07 1.02*
The use of MBLs has made me feel more like a "scientist".	59	3.4	37.3	42.4	16.9	0	3.27	0.78
MBLs haven't increased my level of interest toward science.	58	3.4	10.2	20.3	52.5	11.9	2.40 3.61*	0.95 0.99*
MBL techniques are no more "scientific" than the "traditional" (non-MBL) techniques we have used.	58	1.7	16.9	13.6	37.3	28.8	2.24 3.75*	1.11 1.12*
MBL experiences have made me feel more comfortable around computers.	59	13.6	66.1	16.9	3.4	0	3.90	0.66

How do teachers and students think the MBL approach can be improved here in the province?

The teacher and student responses to statements concerning this question are given in Tables 11 and 12 respectively. Teachers and students think that MBLs should be used in physics courses at least four or five times a year ($\bar{x}$=4.42 and $\bar{x}$=4.41) and students generally agree that they should be used more often in lab sessions ($\bar{x}$=4.32).

Both groups agree that at least two computers should be available strictly for science purposes ($\bar{x}$=4.63 and $\bar{x}$=4.54) and that there is currently not enough MBL equipment in their labs ($\bar{x}$=4.32 & $\bar{x}$=3.88). Students also think they should receive more training in MBL techniques ($\bar{x}$=4.22).

Many teachers indicate that there is not enough time in their lab periods to utilize MBLs ($\bar{x}$=3.57), however, student opinion on this issue appears mixed ($\bar{x}$=2.98). In addition, teachers tend to be split on the matter of having enough time to prepare for MBL activities ($\bar{x}$=2.90).

Table 11
Teacher attitude re: future of MBLs in the province

Statement	(N)	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	Mean	S. D.
	Amount of agreement(%)						(* recoded)	
Physics teachers should use MBLs at least 4 - 5 times a year.	53	49.1	43.4	7.5	0	0	4.42	0.63
There should be at least two computers assigned specifically for science laboratory use.	52	66.0	30.2	1.9	0	0	4.63	0.60
There is not enough MBL equipment in our lab.	53	62.3	22.6	1.9	11.3	1.9	4.32	1.09
I don't have enough time to prepare for MBL activities.	52	18.9	22.6	9.4	41.5	5.7	3.08 2.90*	1.30 1.30*
Science education (methodology) courses offered at universities should include some training in MBL techniques.	53	60.4	39.6	0	0	0	4.60	0.49
There is not enough time in my lab period(s) to use MBL techniques.	52	7.5	11.3	13.2	54.7	11.3	2.48 3.57*	1.09 1.04*

Table 12
Student attitude re: future of MBLs in the province

Statement		Amount of agreement(%)						
	(N)	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	Mean	S. D.
							(* recoded)	
Physics teachers should use MBLs at least 4 - 5 times a year.	58	50.8	39.0	6.8	1.7	0	4.41	0.70
There should be at least two computers assigned specifically for science laboratory use.	59	57.6	39.0	3.4	0	0	4.54	0.57
There is not enough MBL equipment in our lab.	59	32.2	44.1	5.1	16.9	1.7	3.88	1.10
There is not enough time in our lab period(s) to use MBL techniques.	59	11.9	25.4	22.0	33.9	6.8	3.02 2.98*	1.17 1.17*
MBLs should be used more often in our laboratory sessions.	59	39.0	55.9	3.4	1.7	0	4.32	0.63
Students need more training on MBL techniques.	58	32.2	59.3	3.4	3.4	0	4.22	0.68

Have MBL techniques affected teacher attitude toward computers?

The teacher responses pertaining to this question are detailed in Table 13. Teachers believe that MBLs have had a positive effect on their views of computers ($\bar{x}$=4.19) and have increased their interest in computers ($\bar{x}$=4.02). Teachers also seem to be more comfortable in using computers in science as the result of their MBL experiences ($\bar{x}$=3.94). Finally, teachers feel that MBLs have increased their level of computer literacy ($\bar{x}$=3.90).

Table 13
Teacher attitude of MBLs re: affecting attitudes toward computers

Statement	(N)	Amount of agreement(%) Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	Mean	S. D.
							(* recoded)	
MBLs have had a positive effect on my view of computers.	53	28.3	66.0	3.8	0	1.9	4.19	0.68
MBLs haven't increased my interest toward computers.	53	1.9	5.7	11.3	54.7	26.4	2.02 4.00*	0.89 0.92*
MBLs haven't increased my level of computer literacy.	53	0	15.1	3.8	60.4	20.8	2.13 3.90*	0.92 0.93*
I feel more comfortable in the use of computers in science as a result of MBL techniques.	53	20.8	60.4	11.3	7.5	0	3.94	0.79

This chapter began with descriptions of both the teacher and student samples used in this study. A Cronbach α was then stated for the two survey instruments. This was followed by a summary of the results for each research question posed in Chapter 1.

The majority of teachers surveyed indicated that MBLs were used both by students (to collect and analyze data) and themselves (in demonstrations with classes). About 19% of teachers said that students used the MBL equipment and software on their own. A small percentage of teachers indicated that they used MBLs in demonstrations with their classes. As well, a number of teachers and students reported that MBLs have been used in other science courses (chemistry, biology, etc.).

The majority of teachers were using MBLs for 1/4 or less of the time they spent on labs, and approximately 21% of them were using them between 1/4 and 1/2 of the time. A small number of teachers (17%) were using MBLs between 50% and 100% of the time they spent on labs.

The average of the means of the statements given in Tables 3 and 4 are 3.72 and 3.87 respectively. This indicates that teachers and students have an overall positive attitude toward MBL equipment and software.

The average of the means of the statements given in Tables 5 and 6 are 3.86 and 3.90 respectively. This would seem to suggest that teachers and students alike believe that MBLs are having positive effects on the learning that is taking place in laboratory sessions.

The average of the means of the statements given in Tables 7 and 8 are 4.03 and 4.13 respectively. Teachers and students, thus, seem to share the opinion that MBLs enhance their physics courses.

The average of the means of the statements given in Tables 9 and 10 are 3.71 and 3.65 respectively. This would seem to indicate that teachers and students believe that MBLs have positively affected students' attitudes toward science and computers.

The average of the means of the statements given in Tables 11 and 12 are 4.07 and 4.06 respectively. This provides strong evidence that teachers and students think that MBL techniques should be used more often in lab sessions, and that more computer interfacing equipment and computer hardware and software should be allotted for such use. In addition, teachers believe that science methods courses at universities should provide some training in MBL technology, and students feel that they need more training in the use of MBL equipment.

The average of the statements given in Table 13 is 4.01. This clearly indicates that the teachers surveyed believe that MBLs have had positive effects on their attitudes toward computers.

Overall, teachers and students displayed positive attitudes toward MBLs. There are no results on teacher or student survey instruments that suggest any negative attitudes toward MBL use.

CHAPTER 5

DISCUSSION, CONCLUSIONS, and RECOMMENDATIONS FOR FURTHER RESEARCH

A discussion of the results presented in Chapter 4, along with conclusions and recommendations, are included in this chapter. Each of the research questions posed in Chapter 1 will first be restated and briefly discussed

Discussion of Research Questions

To what extent have teachers and students used MBLs?

The results presented in Chapter 4 indicated that there was considerable variation in MBL use by the teachers and students surveyed. There are several possible reasons for the variation in the amount of time spent on MBLs.

First, the availability of both computers and MBL equipment will affect the amount of time that teachers and students use MBL techniques. Teachers who have access to an adequate number of computers and interfacing devices can probably use MBLs as often as they wish. However, as reported in Chapter 4, many of the teachers surveyed for this study have few computers and a limited number of interfacing units available for use in their labs and this may reduce their MBL use. For example, a teacher studying uniform motion with 30 physics students may find it very difficult to effectively use an MBL style lab if he\she has only one or two computers and one or two MBL setups at his\her disposal. The teacher may find it easier to just demonstrate the MBL style and then let the whole class use the readily available traditional equipment (ticker-tape timer, etc.) to do the experiment. Some teachers, knowing that they do not have enough computers and MBL equipment, may forgo the MBL demonstration and just complete the motion lab using the traditional method.

Second, the quantity of computers and interfacing devices may not be the problem, but rather the availability of computer-room time. For example, at a recent physics teachers workshop, several teachers stated that they have plenty of computers and MBL equipment available in their schools to run MBLs, however, the computer-room (where most school computers are located), is "booked solid" with the computer courses being offered. They, therefore, find it next to impossible to effectively run MBLs.

Third, some teachers are comfortable using computers and MBL equipment. These teachers will probably use them as often as they can. However, there are others who are not so comfortable and\or often run into technical problems when using MBL techniques. For these teachers, using MBL methods with their students may be more of a burden than using the traditional style labs that they have used for a number of years.

Fourth, some teachers find that it requires a lot of preparation time in order to use MBLs and this, in many instances, may deter them from pursuing the MBL approach. After all, "prep" time (as it is referred to by many) has increasingly been reduced in many schools for reasons including staff reduction, and an increase in the number of courses being offered in schools.

Fifth, some teachers are eager to try new teaching techniques, new equipment, etc., and many of them adopt new ways of teaching readily. However, other teachers do not want to change their teaching styles or techniques and will no doubt stick to the laboratory methods they have always employed.

Sixth, there are probably a number of teachers who believe that certain labs have to be completed using "traditional" methods. For them, no amount of computer technology can replace some of the neat and simple experiments that have been carried out for years.

What are teachers and students attitudes toward MBL equipment and software?

The data presented in Chapter 4 indicates that teachers and students had an overall positive attitude toward MBL equipment and software. This author believes there are two main reasons for this.

First, the software that accompanies the MBL equipment is easy to use. It is menu driven and user friendly, not unlike much of the software on the market today that many teachers and students have been exposed to.

Second, the MBL equipment is easy to set-up and use. Teachers and students are familiar with many types of science equipment that has been used in their labs. MBL equipment has just added to their inventory and is probably no more difficult to set-up and use then setting up and using an oscilloscope, ticker-tape timer, air track, or digital multimeter. In addition, it is in the nature of science teachers to "fiddle" and "tinker" with science equipment until they have figured it out and can use it.

Do teachers and students believe that MBL techniques enhance student learning?

The data in Tables 5 and 6 presented in Chapter 4 suggests that teachers and students alike believe that MBLs are having positive effects on the learning that is taking place in laboratory sessions. There are a number of possible reasons for this.

First, the real-time data collection, as noted by Brasell (1987) and others in Chapter 2, allows students to see a graph produced as an experiment progresses. Students may make a link between the graph and the physical event being explored and thus gain a better understanding of what is happening. In addition, the graphing capabilities of many MBLs offers an effective means of teaching graphing concepts.

Second, the gathering and graphing (including print-outs) of data in many MBLs takes place fairly quickly. This may give students more time within a lab session to do other things such as: (i) simply repeating procedures in order to average data over a number of trials; (ii) manipulating variables and taking part in "what if" situations; (iii) analyzing data; (iv) focusing on the concepts being studied; and (v) writing lab reports.

Third, students are enthusiastic about using computers and MBLs. This enthusiasm leads to an atmosphere in the lab that promotes thinking and learning.

Fourth, MBLs let teachers and students investigate phenomena that cannot be studied with "traditional" techniques. This brings a certain aspect of creativity and problem solving to the lab which promotes the learning process.

<u>Do teachers and students believe that MBL techniques enhance their physics courses?</u>

The results given in Chapter 4 relating to this question indicate that teachers and students share the opinion that MBLs enhance their physics courses. The author of this thesis suggests two main reasons for this.

First, MBLs offer advantages over traditional style labs. These include (i) quality and accuracy of measurements; (ii) real-time data acquisition; (iii) offering a wider range of possible experiments; (iv) immediate graphing (print-outs) and data analysis capabilities; and (v) allowing more time in the lab to carry out experiments, analyze data, work on lab reports, etc,.

Second, MBLs are interesting, fun, and motivating to teachers and students alike. They not only open the door to endless possibilities for investigating everyday variables, but also utilize state-of-the-art equipment that allow teachers and students to take part in genuine scientific experiences.

Do teachers and students think that MBL techniques have affected students' attitudes toward science and computers?

The results presented in Chapter 4 indicate that teachers and students believe that MBLs have positively affected students' attitudes toward science and computers. There are a couple of possible reasons for this.

First, most students have played computer games and have used various types of software (word processing, subject specific, etc.,). However, before their exposure to MBLs, students had never used a computer in science class to collect and graph data. MBLs have given students a whole new way of using computers. They are excited and enthusiastic about this technology and it directly affects their computer literacy level, view of computers, and interest in science.

Second, students may view the use of computers in the science lab as being more "scientific" than methods they have used before. This may make them feel that they are "doing science" just as researchers and scientists do, thus affecting their view of computers and science.

How do teachers and students think the MBL approach can be improved here in the province?

The results of the statements given in Tables 11 and 12 pertaining to this question suggest several things. First, teachers and students believe that MBLs should be used at least 4-5 times a year and students, in general, would like to see them used more often. They most likely see the many advantages and benefits that MBL techniques bring to the science lab. As well, they may view MBLs as the most current technology available for use in science labs and would like to utilize them as much as possible.

Second, the opinions of teachers and students indicate that they feel more computers should be assigned specifically to science labs, and more MBL equipment should be made available for use in the lab. This probably reflects the idea that many teachers are unable to use MBL activities as often as they would like because of an insufficient number of computers and MBL devices available to them. As more and more money is being spent by school boards for technology purposes, perhaps a focus should be on purchasing computers (specifically for science labs) and MBL set-ups to support a full MBL laboratory.

Third, although the majority of teachers believe that there is enough time in their lab periods to incorporate MBL techniques, there are a number of students who do not think there is enough time. This may be due to the limited amount of time that student groups are allowed to spend at a computer with MBL equipment because other groups have to use the same set-up in the same lab period. In other words, students may want more time to "play around" with the equipment but this may be impossible if there is not enough equipment to go around. Again, a suitable number of computers and MBL units should be made available to the science teachers in any school.

Fourth, approximately 40% of teachers surveyed in this study said that they do not have enough time to prepare for MBL activities. MBL techniques, like many teaching methods, require good planning and preparation. Many teachers these days are faced with decreasing amounts of preparation time in school and as a result, may often become discouraged from using methods that require considerable amounts of time to implement. The point of having an inadequate amount of 'prep' time is often made to principals and school board personnel by many teachers (not just science teachers). If new technologies or teaching methods are to be used by teachers, then enough preparation time must be allocated to teachers so they can effectively and successfully implement such techniques.

Fifth, students seem to want more training in MBL techniques. This probably means that students would not only like to use MBL methods more often, but would also like to explore the many possibilities that could be offered by this MBL technology.

Sixth, teachers surveyed believe that science methods courses at universities should include some training in MBL technology. They no doubt recognize that pre-service science teachers should be given some exposure to MBLs. At the time this research paper was started, none of the science methods courses at Memorial University in Newfoundland provided training in MBLs. However, in the last couple of years, a science lab at Memorial's Faculty of Education has been equipped with computers and computer interfacing equipment and science education professors are utilizing it in their courses. As well, the Faculty of Science at Memorial University now has a fully equipped MBL laboratory in the physics department that is used in some sections of first-year physics courses.

<u>Have MBL techniques affected teacher attitude toward computers?</u>

The results presented in Chapter 4 clearly show that the teachers surveyed believe the use of MBLs have had a positive effect on their attitudes toward computers. There are a few possible reasons for this.

First, teachers probably see the potential that MBLs offer for their classes. Being able to measure quantities (with great precision) and explore problems never dreamt possible before would certainly seem to effect their view of computers.

Second, many of the teachers surveyed grew up and went to school and university in an era prior to the introduction of computers in educational settings. Being trained in MBL techniques and subsequently using them with students may be, for some teachers, their initial use of computers in their courses. Therefore, they are excited and enthusiastic about such technology. Even if some teachers have used computers and software programs with their students before, they may find that MBL technology has given them a more direct "scientific" way of utilizing computers with their students.

Third, teachers may recognize a certain enthusiasm and interest that students display toward computers and computer interfacing equipment in the science lab. This no doubt affects teachers' attitudes toward computer use.

Finally, science teachers may feel that the use of computers and MBL technology has given them skills that make them a part of the "scientific community". After all, there are very few scientists and researchers in today's world who do not use computers in the collection, analysis, and presentation of scientific data.

Conclusions

Based on the results presented in Chapter 4 and the discussion of the research questions in this chapter, the author proposes the following conclusions:

1. Many teachers and students in this province are using MBLs in their physics courses to collect and analyze data. Most are using them between 1/4 or less of the time that they spend on labs, however, some are using them more often.

2. MBLs are being used by some teachers and students in courses other than physics (such as biology and chemistry).

3. Most teachers have one or two computers available for use in MBLs. There are a few teachers who have access to three or more computers.

4. The majority of teachers have one set of MBL equipment available to them for use in MBLs. There are a few teachers who have more than one MBL set-up at their disposal.

5. Teachers and students have an overall positive attitude toward MBL equipment and software.

6. Teachers and students alike believe that MBLs are having positive effects on the learning that is taking place in lab situations.

7. Teachers and students believe that MBL techniques are enhancing their physics courses.

8. Teachers and students believe that MBLs have positively affected students' attitudes toward science and computers.

9. Teachers believe that MBLs should be used in their physics courses at least 4 or 5 times a year.

10. Students would like to see MBLs used more often in their laboratory sessions.

11. Teachers and students would like to see more computers assigned specifically for science lab use.

12. Teachers and students would like to see more MBL equipment available for use in MBLs.

13. School administrators and School Board personnel should recognize that an adequate amount of preparation time is needed by all teachers to successfully plan and prepare for the teaching of their courses.

14. Teachers believe that MBLs have had positive effects on their attitudes toward computers.

15. MBL workshops should be offered by all the boards across this province, not only to interested high school science teachers, but also to elementary and junior-high science teachers.

Recommendations for Further Research

Based on the findings of this research, the following recommendations are made:

1. In order to get information that we can be certain represents the attitudes of Newfoundland and Labrador students, a large random sample study of students sufficiently exposed to MBLs would be needed. Such a study could give additional information. However, the positive attitudes of teachers and students found here are so consistent, little additional information is likely to be gained.

2. A future study pertaining to MBL use in Newfoundland and Labrador should focus on the Distance Education physics and chemistry students. These students have extensively used MBL technology and are, therefore, more likely to give a picture of students' attitudes in a situation where MBLs have been fully incorporated into teaching.

3. Many of the MBL studies reported on in Chapter 2 make use of motion and temperature probes to study motion and temperature concepts with students. Future MBL studies should focus on other types of probes available such as force probes, sound/microphone probes, etc,.

4. Future studies could also focus on whether or not positive attitudes toward MBLs lead to more learning, further course taking in science, or other desirable ends.

Synopsis

This study investigated the attitudes that teachers and students have toward microcomputer-based laboratories (MBLs) in the province of Newfoundland and Labrador. Results of teacher and student surveys indicate that the respondents have an overall positive attitude toward MBLs. The computer has been and will continue to become an important educational resource for educators. Students' and teachers' positive attitudes toward this technology should encourage its use.

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Appendix A

Teacher Questionnaire Instrument

MICROCOMPUTER-BASED LABORATORIES – TEACHER SURVEY

This survey instrument will help me gain an understanding of your attitudes toward Microcomputer-Based Labs (MBLs). These are the laboratory/classroom situations in which you and/or your students use a computer to gather and analyze data (you may be using the Vernier system, the Super-Champ system, or both). Please take a few moments to answer all questions. If you wish to make a comment on or qualify an answer, use the space in the margin. I thank you for your participation. **DO NOT PUT YOUR NAME ON THIS SURVEY**.

W. Robert Swyer
Graduate Student, Science Curriculum and Instruction
Memorial University of Newfoundland
St. John's

Section A **Circle your response to the following questions.**

1. How are Microcomputer-Based Laboratories (**MBLs**) used in your lab/classroom?
   - A. Students collect and analyze data using the MBL equipment and software.
   - B. I use the MBL equipment and software to demonstrate to the class.
   - C. Both A and B.
   - D. Other (explain) ________________

2. How many computers are available for use in your lab/classroom ?
   A. 1 B. 2 C. 3 D. >3

3. How many computer-interfacing units does your school have ?
   A. 1 B. 2 C. 3 D. >3

4. How often do you have physics labs (not just MBL sessions, but labs in general)?
   - A. Every week.
   - B. Every couple of weeks.
   - C. Every three weeks.
   - D. Other (tell how often) ________________

5. Keeping in mind your response to question 4 above, approximately what % of time do you and/or your students use MBL techniques in the lab ?
   - A. 75% - 100%
   - B. 50% - 74%
   - C. 25% - 49%
   - D 0% - 24%

6. In what other science courses have you used MBL techniques (you may circle more than one)?
   - A. Chemistry
   - B. Biology
   - C. Other (name) ________
   - D. none

7. Students usually perform MBLs in groups of:
   - A. 2
   - B. 3
   - C. 4
   - D. >4

Section B

Below are several statements concerning Microcomputer-Based Laboratories (MBLs). Based on your experiences, please indicate how much you agree or disagree with each statement by circling the **ONE** response that comes closest to how you think.

Use the following scale:

SD	D	U	A	SA
STRONGLY DISAGREE	**DISAGREE**	**UNDECIDED**	**AGREE**	**STRONGLY AGREE**

1. The computer software associated with MBLs is easy to use.	SD	D	U	A	SA
2. Students are able to use the MBL computer software on their own.	SD	D	U	A	SA
3. Physics teachers should use MBLs at least 4-5 times a year.	SD	D	U	A	SA
4. I don't see any advantages of using MBLs over the "traditional" (non-MBL) labs.	SD	D	U	A	SA
5. MBLs have increased students' levels of computer literacy.	SD	D	U	A	SA
6. MBLs have helped students in interpreting and drawing conclusions from data.	SD	D	U	A	SA
7. There should be at least two computers assigned specifically for science laboratory use.	SD	D	U	A	SA
8. The printed material that comes with the MBL equipment (i.e., manuals or guides that accompany the Vernier and/or Super-Champ systems) is easy to follow and helpful.	SD	D	U	A	SA
9. MBLs haven't had a positive effect on students' views of computers.	SD	D	U	A	SA
10. MBL tools offer an effective means of teaching graphing concepts.	SD	D	U	A	SA
11. MBLs make students feel more like "scientists".	SD	D	U	A	SA
12. MBLs have had a positive effect on my view of computers.	SD	D	U	A	SA
13. There is not enough MBL equipment in our lab.	SD	D	U	A	SA
14. Because MBLs reduce the time needed for data collection, students are able to "think critically " about what they are doing.	SD	D	U	A	SA

Use the following scale:

SD	D	U	A	SA
STRONGLY DISAGREE	DISAGREE	UNDECIDED	AGREE	STRONGLY AGREE

15. I find it difficult to set up the MBL equipment for any given experiment.	SD	D	U	A	SA
16. MBLs have had positive effects on students' attitudes toward doing laboratory assignments.	SD	D	U	A	SA
17. MBLs haven't increased my interest toward computers.	SD	D	U	A	SA
18. MBLs haven't changed students' levels of interest toward science.	SD	D	U	A	SA
19. MBLs are no better than the "traditional" (non-MBL) labs when it comes to students' understanding of concepts.	SD	D	U	A	SA
20. MBLs haven't enhanced my physics course(s).	SD	D	U	A	SA
21. I feel somewhat intimidated by the MBL equipment and software.	SD	D	U	A	SA
22. Students don't view MBL techniques as any more "scientific" than the "traditional" (non-MBL) techniques they have used.	SD	D	U	A	SA
23. I don't have enough time to prepare for MBL activities.	SD	D	U	A	SA
24. Students find MBLs more interesting than "traditional" (non-MBL) laboratory sessions.	SD	D	U	A	SA
25. Since MBL equipment can process data quickly, more cases or situations involving a concept can be analyzed in a lab session. i.e., more time for trying different approaches or different "angles".	SD	D	U	A	SA
26. I often run into "technical" difficulties when using MBL techniques.	SD	D	U	A	SA
27. MBL experiences have made students feel more comfortable around computers.	SD	D	U	A	SA
28. Science education (methodology) courses offered at universities should include some training in MBL techniques.	SD	D	U	A	SA
29. I don't believe that students' science learning has benefitted from the incorporation of MBLs.	SD	D	U	A	SA

Use the following scale:

SD	D	U	A	SA
STRONGLY DISAGREE	DISAGREE	UNDECIDED	AGREE	STRONGLY AGREE

30. Using "modern" technology such as MBLs is fun, motivating, and adds to the quality of my physics course(s).	SD	D	U	A	SA
31. MBLs haven't increased my level of computer literacy.	SD	D	U	A	SA
32. Students find MBLs enjoyable and stimulating.	SD	D	U	A	SA
33. I feel more comfortable in the use of computers in science as a result of MBL techniques.	SD	D	U	A	SA
34. There is not enough time in my lab period(s) to use MBL techniques.	SD	D	U	A	SA

Almost finished !!

One more page to go -------->

Section C

Male___ Female ___

Age: ___ < 25 ___ 25-30 ___ 31-35 ___ 36-40 ___ 41-45

___ 46-50 ___ 51-55 ___ > 55

Degree(s) held: B.Sc. ___ B.A. ___ B.Ed. ___ M.Ed. ___ M.Sc. ___

M.A. ___ Other (name) ____________________

Area of Major: Math ___ Physics ___ Chemistry ___ Biology ___

Earth Science ___ Other(name) _____________

Area of concentration (after major)

Math ___ Physics ___ Chemistry ___ Biology ___

Earth Science ___ Other(name) _____________

Teaching Experience (# years): ____ (up to and including 1993-94).

Main area of teaching responsibility: ___________________

Secondary area of teaching responsibility: ___________________

Number of computer course credits obtained through university or technical college ____

I feel that my computer knowledge is : low ___ average ___ above average ___

Computer-interfacing equipment you are using :

Vernier ___ Super-Champ ___ Other(name) ________________

Thank-You for your time and cooperation.

Appendix B

Student Questionnaire Instrument

MICROCOMPUTER-BASED LABORATORIES -- STUDENT SURVEY

This survey instrument will help me gain an understanding of your attitudes toward Microcomputer-Based Labs (MBLs). These are the laboratory/classroom situations in which you and/or your teacher use a computer to gather and analyze data (you may be using the Vernier system, the Super-Champ system, or both). Please take a few moments to read and respond to all questions and statements. If you wish to make a comment on or qualify an answer, use the space in the margin. I thank you for your participation. **DO NOT PUT YOUR NAME ON THIS SURVEY.**

W. Robert Swyer
Graduate Student, Science Curriculum and Instruction
Memorial University of Newfoundland
St. John's

Section A

Male___ Female ___

Level ____

Science courses you are now taking	Subject	Course Number
	______	______
	______	______
	______	______

Science courses already completed	Subject	Course Number
	______	______
	______	______
	______	______

Computer courses you are now taking	Subject	Course Number
	______	______
	______	______
	______	______

Computer courses already completed	Subject	Course Number
	______	______
	______	______
	______	______

I feel that my computer knowledge is : low __ average __ above average __

I feel that I like science : less than average __ about average __ more than average __

Have you used MBLs in science course(s) other than physics ? __ yes __ no

If you answered "yes" to the last question, name the course(s).

____

____

Section B

Below are several statements concerning Microcomputer-Based Laboratories (MBLs). **(Don't forget, MBLs are lab/class situations in which a computer is used to gather and analyze data. You may be using the Vernier system, the Super-Champ system, or both).** Based on your experiences, please indicate how much you agree or disagree with each statement by circling the **ONE** response that comes closest to how you think.

Use the following scale:

SD	D	U	A	SA
STRONGLY DISAGREE	DISAGREE	UNDECIDED	AGREE	STRONGLY AGREE

1. The computer program (software) associated with MBLs is easy to use.	SD	D	U	A	SA
2. Once the equipment for a particular MBL experiment is set up, I can easily "run" the experiment several times.	SD	D	U	A	SA
3. Physics teachers should use MBLs at least 4-5 times a year.	SD	D	U	A	SA
4. I don't see any advantage that MBLs have over the "traditional" (non-MBL) labs we have always done.	SD	D	U	A	SA
5. MBLs have increased my knowledge and understanding of computers.	SD	D	U	A	SA
6. MBLs have helped me in interpreting and drawing conclusions from data.	SD	D	U	A	SA
7. There should be at least two computers assigned specifically for science laboratory use.	SD	D	U	A	SA
8. I often run into problems when using the MBL equipment and software.	SD	D	U	A	SA
9. MBLs have not changed my view of computers.	SD	D	U	A	SA
10. MBLs haven't increased my graphing capabilities.	SD	D	U	A	SA
11. The use of MBLs has made me feel more like a "scientist".	SD	D	U	A	SA
12. I find MBLs enjoyable and stimulating.	SD	D	U	A	SA
13. There is not enough MBL equipment in our lab.	SD	D	U	A	SA

Use the following scale:

SD	D	U	A	SA
STRONGLY DISAGREE	DISAGREE	UNDECIDED	AGREE	STRONGLY AGREE

14. Because MBLs reduce the time needed for data collection, I am better able to concentrate on what's "going on" in an experiment.	SD	D	U	A	SA
15. I would not be able to set up MBL equipment by myself.	SD	D	U	A	SA
16. MBLs have had a positive effect on my attitude toward doing laboratory assignments.	SD	D	U	A	SA
17. There is not enough time in our lab period(s) to use MBL techniques.	SD	D	U	A	SA
18. MBLs haven't increased my level of interest toward science.	SD	D	U	A	SA
19. MBLs are no better than the "traditional" (non-MBL) labs when it comes to the understanding of concepts.	SD	D	U	A	SA
20. I don't think that MBLs have enhanced our physics course(s).	SD	D	U	A	SA
21. I can easily print data (tables and graphs) after the data has been gathered by the MBL equipment.	SD	D	U	A	SA
22. MBL techniques are no more "scientific" than the "traditional" (non-MBL) techniques we have used.	SD	D	U	A	SA
23. MBLs should be used more often in our laboratory sessions.	SD	D	U	A	SA
24. MBLs are more interesting than "traditional" (non-MBL) laboratory sessions.	SD	D	U	A	SA
25. Since MBL equipment can process data quickly, more cases or situations involving a concept can be analyzed in a lab session. i.e., more time for trying different approaches or different "angles".	SD	D	U	A	SA
26. MBL equipment is hard to use.	SD	D	U	A	SA
27. MBL experiences have made me feel more comfortable around computers.	SD	D	U	A	SA
28. Students need more training on MBL techniques.	SD	D	U	A	SA
29. MBL techniques have not enhanced the learning that takes place in our labs.	SD	D	U	A	SA
30. Using "modern" technology such as MBLs is fun, motivating, and adds to the quality of our physics course(s).	SD	D	U	A	SA

Thank-You very much for your time and cooperation.

Appendix C

Teacher Consent Form

Dear Teacher:

I am a Graduate Student enrolled in a Masters of Education program (Curriculum and Instruction - Science) at Memorial University in St. John's. My supervisor, Dr. Glenn Clark, and I are attempting to determine the attitudes that the teachers and students of this province have toward Microcomputer-Based Laboratories (MBLs). I am requesting your permission to include you in this study.

If you decide to participate, you will be asked to complete and return a questionnaire consisting of three parts. The first section consists of some general questions on your use of MBLs. In the second part, you will be asked to respond to Likert-type statements in order to help determine the attitudes you have toward MBLs. Finally, the third section will seek information such as age, degree(s) held, and teaching experience. It will take you approximately 20 minutes to complete all questions.

All information will be strictly confidential and the results will be reported on a group basis only. Also, the findings are available upon request. Your participation is voluntary and you may withdraw at any time. This research has been approved by the Faculty of Education's Ethics Review Committee.

If you agree to participate in the study, please sign, date and return this form to me along with the surveys. If you have any questions or concerns, contact me at 737-2069 (MUN) or 364-1396 (home). In addition, Dr. Patricia Canning, Associate Dean, Research and Development, Faculty of Education, is acting as a resource person and is not directly associated with the study. She can be contacted at 737-3402. Thank-you for your time and consideration.

Yours Sincerely;

W. Robert Swyer

I ____________ hereby agree to take part in a study of the attitudes that teachers and students have toward Microcomputer-Based Laboratories. I understand that my participation is voluntary and that I can withdraw my permission at any time. All information gathered will be strictly confidential and no individual will be identified.

________ ______________ Date Participant's Signature

Appendix D

Student Consent Form

Dear Student:

I am a Graduate Student enrolled in a Masters of Education program (Curriculum and Instruction - Science) at Memorial University in St. John's. My supervisor, Dr. Glenn Clark, and I are attempting to determine the attitudes that the teachers and students of this province have toward Microcomputer-Based Laboratories (MBLs). I am requesting your permission to include you in this study.

Your participation will consist of completing a questionnaire consisting of two parts. The first section will seek information such as your sex, grade level, and science courses completed. In the second section, you will respond to Likert-type statements in order to help determine the attitudes you have toward Microcomputer-Based Laboratories. It will take you approximately 15-20 minutes to complete all questions.

All information will be strictly confidential and the results of the study will be reported on a group basis only. Also, the findings are available upon request. Your participation is voluntary and you may withdraw at any time. This research has been approved by the Faculty of Education's Ethics Review Committee.

If you agree to participate in the study, please sign, date and return this form (along with the survey) to the teacher involved. If you have any questions or concerns, please see this teacher. In addition, Dr. Patricia Canning, Associate Dean, Research and Development, Faculty of Education, is acting as a resource person and is not directly associated with the study. She can be contacted at 737-3402. Thank-you for your time and consideration.

Yours Sincerely;

W. Robert Swyer

I __________ hereby agree to take part in a study of the attitudes that teachers and students have toward Microcomputer-Based Laboratories. I understand that my participation is voluntary and that I can withdraw my permission at any time. All information gathered will be strictly confidential and no individual will be identified.

________ ______________Date Student's Signature

Appendix E

Example School Board Consent Form

20 Third Street
Mount Pearl, Nfld.
A1N 2A5

Superintendent
[School District and Address]

Dear Sir:

I am a Graduate Student enrolled in a Masters of Education Program (Curriculum and Instruction - Science) at Memorial University in St. John's. My supervisor, Dr. Glenn Clark, and I are attempting to determine the attitudes that the teachers and students of this province have toward Microcomputer-Based Laboratories (MBLs). I am requesting your permission to include some of your Board's teachers and students in the study.

By participating, the teachers and students involved will be asked to complete and return a questionnaire consisting of two parts. The first section will seek general information such as age, degree(s) held, teaching experience, grade, science courses completed, etc. The second section will determine the attitudes the teachers and students have toward MBLs by means of an instrument consisting of Multiple-Choice and Likert-type questions. It will take approximately 20-25 minutes for the teachers and students to complete all questions.

All information will be strictly confidential and results of the study will be reported on a group-basis only. A summary of the findings will be available upon request. The teacher's and student's participation is voluntary and they may withdraw at any time. This research has been approved by the Faculty of Education's Ethics Review Committee.

If you agree to allow some of your teachers and students to participate in the study, please sign, date and return this form to me (if you wish, you can fax your response to 737-2429). If you have any questions or concerns, contact me at 737-2069 (MUN) or 364-1396 (home). In addition, Dr. Patricia Canning, Associate Dean, Research and Development, Faculty of Education, is acting as a resource person and is not directly associated with the study. She can be contacted at 737-3402.

Thank-you for your time and consideration.

Yours Sincerely,

W. Robert Swyer

I ___________ hereby grant permission for some teachers and students of my School Board to take part in a study of the attitudes that teachers and students have toward Microcomputer-Based Laboratories. I understand that their participation is voluntary and that they or the Board can withdraw permission at any time. All information gathered will be strictly confidential and no individual will be identified.

________ ____________

Date Signature