

Using CBL 2 Technology to Promote Inquiry and to Improve Interpretation of Graphs in

High School Science

by

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## Abstract

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Combining inquiry with Microcomputer Based Laboratory (MBL) technology such as Calculator Based Laboratory 2 (CBL 2) and improving science literacy are ideas that Project 2061 support.

In this study, two grade-eight classes learned about heat energy transfer. Participants in the control group learned using a traditional approach and used no CBL 2 technology. Students in the experimental learned using guided inquiry and CBL 2 technology. Student pre and post-test data came from two graph interpretation tests, TOGS (1986) and GIST (1999). Qualitative data were collected using interviews and journal writing.

Comparison of pre and post-test means indicated a statistically significant improvement for both groups in their abilities to interpret graphs. Also, a greater percent of experimental students demonstrated individual improvement. Interviews indicated that experimental students did their own learning and were better problem solvers. Technology provided students with positive attitudes and motivation as they learned science from an inquiry perspective.

Supervisor: Dr. Kathie Black

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## Chapter 1: Introduction

The next time you visit a science classroom take a look around and observe what is happening. In those science classrooms that I have watched, (and I include here, of course, my own) the following situations have commonly occurred. In the typical classroom, one finds a teacher who, after settling everyone down, presents some material in the form of notes, and then explains the project, or outlines the procedure for that day's experiment. Is this science? Are the students engaged in activities that simulate the scientists performing research in our country? Are the students incorporating prior knowledge, building on what they and others know, making predictions, observations, and generalizing findings into natural laws that rule our world? However, one may say, "they are children they are not scientists" but I say, who better to learn a new way of thinking and acting than a child?

### *Background leading to the research problem*

There is a "widespread public perception that something is seriously remiss in our educational system." These are the words of T. H. Bell, the secretary of education for the United States National Commission for Excellence in Education (NCEE). A proposal in order to investigate problems in education began in 1981, and by 1983, NCEE released the report *A Nation at Risk*. The United States was at risk in commerce, industry, technology, and science. Inadequate education of the public looked like the reason for this challenge. "If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war" (NCEE, 1983, *A Nation at Risk*, para. 2). The concerns in the report do not

center only on America's inability to compete globally, it was rather that an insufficient education system was eroding society's intellectual, moral, and spiritual strength.

A country that prided itself on providing a quality education regardless of social status, gender, and race was failing its people. *A Nation at Risk* provided overwhelming evidence that supported the claims that the United States had an inferior education system. For the first time in America's history, the next generation had failed to surpass the preceding generation in educational competencies. The report concluded that the declines in educational performance were not only the result of poor content but also because of the processes of instruction. Something needed to be changed about instruction and quickly.

In a response to research that put the United States well behind other countries, 12<sup>th</sup> place out of 12 countries in Mathematics (Husen, 1967), and in science behind Korea, Taiwan, Hungary, and Canada to name a just few (Lankard, 1993) reforms in science and mathematics became a high priority. In 1989, the National Council of Teachers of Mathematics (NCTM) presented the *Curriculum and Evaluation Standards for School Mathematics*, a document that reflected the need for mathematical literacy. Their goals for students were: 1. learn to value mathematics; 2. become confident in their ability to do mathematics; 3. become mathematical problem solvers; 4. learn to communicate mathematically; and, 5. learn to reason mathematically (NCTM, 1989). In order to meet these goals it would be necessary to introduce new content and learning methods. A recent revision of these standards in 2000 continued to reflect new findings and to provide further support in order to reach the above stated goals.

While the mathematics community was working to deal with the deficiencies seen in their subject areas, science organizations began to put together similar responses and solutions to improve science. In 1985, the American Association for the Advancement of Science (AAAS) started Project 2061. In 1989, AAAS proposed a reform for science education by publishing *Science for All Americans* (SFAA). The goal for Project 2061 was to create a public that was literate in science, mathematics, and technology in an average human life span of 76 years (actually the 76 years corresponds to the time it will take Hailey's comet, that was last seen in 1985, to return).

To combat a world shaped by science and technology it becomes necessary to create an educated public that is scientifically literate and therefore more prepared to meet demands of the future. Science literacy is having knowledge about the natural world, understanding of basic science concepts, seeing the connections between math, science and technology, and using scientific knowledge in one's personal and social decision-making (AAAS, 1989).

Reform in the education system is necessary in order to achieve scientific literacy. Mathematics and technology are two areas of study that will play a major role in the reform of science education. Mathematics is the language and grammar of science and shares many of the same beliefs such as imagination, peer criticism, and foundational discoveries (AAAS, 1989). Areas of science that are important for students to learn during their schooling span astronomy, geology, geography, chemistry, biology, and physics.

In developing the scientifically literate individual, thinking skills also known as content domains associated with sciences and mathematics are vital and demands our

attention. Good attitudes, skills, and values have been a priority in teaching individuals in society (AAAS, 1989). We are to instill these same necessary attributes in our students by developing good thinking skills but from a scientific perspective. Science and technology are creating the future and it is the responsibility of the education system to teach how to deal with the future, not just learning about the past. Learning how to deal with new ideas that may be contrary to the present way of thinking or doing something is a thinking skill necessary for dealing with the future. As noted by AAAS, teaching by building on the innate curiosity of students, working within a team setting, exploring, and experimenting will engage students and learning will result (AAAS, 1989). Presenting material and having students learn the material in this manner fosters the necessary thinking skills needed for the future. Such skills include making inferences, estimations, and applying those skills in conjunction with technology. Being able to determine if the results are reasonable is a valued thinking skill. Other noteworthy habits of scientifically literate people include manipulating and observing, storing and retrieving data, reading instruments, setting up circuits used in technical equipment, and troubleshooting. One final skill is the correct interpretation of data in order to avoid inferences from misleading graphs or statistical data, a necessary skill to thrive in the future.

In order to accomplish the needed reform in science education it is necessary to focus on subject presentation, on how to produce such lasting and significant change, and on what institutions and personnel will be needed to produce the change. Again, as stated by AAAS, teacher success can result when the focus is on quality, not quantity, and meaningful and varied formats of concept presentation (AAAS, 1989). Good science teaching can promote curiosity, creativity, and thoughtful inquisitive questions. Students

are encouraged to *play*, using different combinations to explore ideas as well as taking the time to make full and complete analysis. Learning cannot be rushed.

The need for a better-educated society is apparent. However, plans for change, no matter how well developed, take time. The collaboration between all involved parties: governments, associations, administrators- with teachers as the central core, are essential (AAAS, 1989). The changes presented apply to all levels of the public- no child is to be left behind.

In 1993, *Benchmarks for Science Literacy* was introduced as the second step in Project 2061's plan for reform in science education. One learns science by doing science. As students gain experience doing science, they become more sophisticated in conducting investigations, and explaining their findings. Furthermore, students will accumulate a set of concrete experiences and use this knowledge as they reflect on their investigations (AAAS, 1993). Scientific engagement calls for frequent hands-on activities. However, one cannot experience all science directly. When the individual through careful and accurate observation discovers rules of science, the learning that takes place is powerful. In this present day, the technology available allows for recreation of the rules and rediscovery of scientific laws. The teacher can be the guide and provide some input; however, the teacher is not the sage. Again as seen in SFAA (1989), *play* is key. Questions like: How can we determine if a reaction is between a strong base and strong acid or another combination? Or, how do we know that absolute zero is  $-273.15\text{ }^{\circ}\text{C}$ ? Emphasis is on the student and questions such as, what is necessary to answer these questions and how could we use technology? are ideally for the students' asking, not the

teachers. Students are to begin to frame questions, design the approach, conduct trial runs, and write reports. Students are to be learning and acting as scientists.

In science class, the questions studied are to be open-ended and lead to new areas of study. As questions progress, students are to be encouraged to be more observant, and gain skills in recording and interpreting data. As students learn about the inquiry into science, the experiments they will do may even last for weeks simulating the conduction of real science. Science is not just about collecting data, solving problems, and writing papers. Students need an exposure to science as an enterprise. Science can be a business involving team collaboration, generating public or private funding for research, and competing with other researchers. Within the realm of science, there are social and ethical issues, as well as the role of scientists in public affairs. Introducing science as a possible career may help students see the role of science in society (AAAS, 1993).

Mathematics is important; it is the language of science. Investigations using technology help make connections between math and science. Linear relationships have real life applications. Data that represent such relationships are to be included in the study of science. One cannot learn and understand science without mathematics (AAAS, 1993).

Technology allows students to see where they could not and provides opportunity to reinvestigate some historical discoveries. Students can see first hand topics such as  $K_a$  values, pH change, and enthalpy change as opposed to having a lecture. AAAS (1993) mentions that students often memorize the names of invisible things and their parts. Ideally, students should learn concrete perceptions before abstract explanations (AAAS, 1993). Technology can aid in making connections between the motion of molecules and heat energy. Motion of molecules or even the notion that matter is composed of

molecules is an abstract idea but is foundational to the study of chemistry. Gas pressure sensors aid in visualizing theories such as the kinetic molecular theory. AAAS (1993) promotes the use of computer-based probes and graphic displays that can detect small changes in temperature and then plot those changes as students learn abstract ideas such as heat and its different methods of transfer.

Students should first become familiar with what they are investigating by experiencing concrete examples prior to presentation of abstract theories (AAAS, 1993). Ideas such as these are present throughout this document and coincide with similar thoughts presented by Alfred North Whitehead in his *Aims of Education* (Whitehead, 1929/1967). Students do not necessarily need to believe all aspects of the science that they are studying, but all students by the end of grade 12 are to be familiar with major science phenomena. Science can be a medium for students learning how to learn skills that even the non-science person is to acquire in their education. The study of science is not just about studying natural events but to see an event from multiple perspectives. Project 2061 views science literacy as knowledge needed for problem solving, making decisions, understanding and learning more about the world (AAAS, 1993).

Developing a sense of what equations are and how they correspond to other ways of expressing relationships among things is more important for science literacy than being able to derive or use them. Students who take a year or more of algebra often learn to manipulate symbols and solve equations (at least until exam time) but come away with little grasp of what a solution means or why anyone would want it (AAAS, 1993, Chapter 9 Section B, para. 3).

By integrating mathematics and science, equations can have meaning. Often overlooked is the significance of the Y intercept in linear equations. Explorations such as determining the value of absolute zero bring about new and important meaning to Y intercepts. Real world problems bring with them real world data. Questions such as, “why is the value that we found in our lab not the same as the value in the text?” provide opportunities to investigate real issues in science and math for the world does not seem to act as simply as mathematics (AAAS, 1993).

Technology can provide useful methods for modeling scientific events. Taking an event that one understands and applying it to something they do not makes modeling a powerful learning method (AAAS, 1993). Graphs provided by technology can coincide with the science literacy goal of creating a public where people have some knowledge of how to read and interpret a graph. When students see how powerful the technology is they begin to think differently on how to solve problems. Also being able to use technology is a scientific literacy goal. Although hands-on experience may give the impression that meaningful learning is occurring, reflection on what is happening, verbally or written, is fundamental for learning. Needed reform is about moving from thoughtless memorization and answers to ensuring that students are engaged in a wide variety of activities that promote science, math and technology (AAAS, 1993).

In 1995, the Council of Ministers of Education in Canada adopted a strategy to increase the collaboration on school curriculums between provinces. The primary goal for the science curriculum, like its American counterparts, was to increase the public’s scientific literacy. Similar to *Benchmarks for Science Literacy*, the Pan-Canadian Framework was to act as a guide for those developing a curriculum. Canadians, like the

Americans, saw the usefulness of science education in promoting science literacy and in building a stronger future for the Canada's youth (Pan-Canadian Framework, 1995). The Pan-Canadian Framework document establishes four foundational goals for obtaining scientific literacy. Firstly, science, technology, society, and environment (STSE). In this goal students would learn about the relationships between science, technology, society, and the environment. Students would also learn about methods to strengthen society and increase ones' concern for the environment. Secondly, skills – develop skills needed for science and technology. Promote inquiry, problem solving, working with others, and making informed decisions. Thirdly, knowledge – strengthening the understanding of major concepts in the life, physical, earth and space sciences and applying them. Finally, attitudes – creating ways to promote how science mutually benefits self, society, and the environment and supporting the responsible gathering and application of scientific ideas. Other ideas presented in documents preceding this framework include: connections to other subjects, emphasis on use of technology, hands-on discovery based learning, alternate assessment techniques, application of science, and movement from a terminology based science to understanding the nature of science.

The release of another supportive document for science literacy came in the following year, 1996. In the United States, it was the National Science Education Standards (NSES), funded by the National Science Foundation. The NSES presented a way of teaching and learning science that emphasizes inquiry as a method to gain knowledge and understanding about the world (NRC, 1996).

In order for change to occur, barriers such as change in curriculum, change in teacher knowledge and strategies, and increasing public, including family, awareness and

participation in education were necessary. *Benchmarks for Science Literacy* and SFAA address this issue. Education of teachers is a huge hurdle to clear. Project 2061 documents that in many cases, teachers have had poor role models for teaching science and in other cases; the teachers themselves do not want to change their practices (AAAS, 1997). Policy changes initiated by the government are vital to promoting changes in curriculum and teacher education. Many teachers require quality professional development that models good science literacy skills.

Research on determining the best methods to bring about change is progressing (O'Neill & Polman, 2004; Zion et al., 2004). Methods that utilize hands-on and discovery learning promote good science literacy. Teaching that demonstrates connectiveness between other disciplines and with society are very beneficial and is most effective at the local level. For the last 20 years, many different organizations and documents have proposed plans for creating the scientifically literate individual. Throughout these plans for reform there are many common ideas woven into each document. It is important for a student to understand what is *science* and how do you know when *science* is occurring. The use of history as a method to teach about science and the process of science occurs in many of these documents. Learning strategies that put the students in the position as scientists doing hands-on investigations, inquiry based learning, and inclusion of prior knowledge are stated as foundational for the development of a scientifically literate individual. Hands-on, inquiry-based methods, and using technology as a tool for learning, enhances the learning experience. In developing and nurturing the scientifically literate individual, science reform has moved from emphasizing memorization and recitation to exploration, critical thinking, and understanding.

### *Problem Statement*

Students often learn science as facts and rarely have an opportunity to discover ideas by doing hands-on explorations that involve their own procedures. Technological tools provide an opportunity for students to problem-solve and model how scientists perform science. Many students struggle with interpreting graphs. One aspect of becoming scientifically literate is to gain skills in graph interpretation. Technological tools provide an opportunity for students to spend more time analyzing the graphs because the technology collects and creates the graphs for the students. Project 2061 stresses inquiry and science literacy as important qualities. This study is important for it focuses on providing a practical method for incorporating these attributes into the present British Columbia science curriculum.

To explore science literacy related issues, the researcher developed the following questions:

Research Question One (RQ1): Does hand-held technology, CBL 2, help promote guided inquiry, hands-on based teaching methods? If so, to what degree?

Research Question Two (RQ2): Does the use of hand-held technology, CBL 2, help improve student graph interpretation skills?

### *Rationale*

In order to address this issue, the researcher developed a technology intensive unit for the science eight curriculum. In this unit, students were to use CBL 2 technology over a two-week period to explore the concepts of heat energy transfer. Heat energy transfer is a unit in the B.C. grade eight-science curriculum. Goals for this unit were for students to

use technology to facilitate learning about heat energy transfer from a guided inquiry perspective. A further goal was for students to improve their ability to interpret graphs by having the opportunity to spend more time reading and interpreting graphs as opposed to spending time creating the graphs by hand and then having less time to interpret them.

The research questions explore whether students can be engaged in inquiry based study while using technology. There have been many advances in computer technology that provide opportunity to collect data and create graphs from real-world situations. One of these advances is improvement in hand-held technology.

An example of a hand-held technological device is the Calculator Based Laboratory (CBL 2). When attached to a Texas Instrument (TI) graphing calculator this technology offers some unique advantages over computer technology. Smaller in size and lower in cost, compared to personal computers, the CBL 2 allows for more opportunities for students to handle and operate technological equipment. This means that a greater number of students have opportunities to experiment and explore the scientific concepts first hand, emphasizing the students as dynamic participants in learning and creating an atmosphere where students can be more like scientists.

Instruments such as a CBL 2 in the hands of students may help lead them to discover concepts using interesting and valuable methods, therefore, reinforcing the scientific process of discovery. This technology may allow students to act as scientists as opposed to passively gaining scientific knowledge through use of pre-made data or low level question answering. Technology associated with computers increases the speed and accuracy of data collection, therefore making simulation of past discoveries more realistic. With the aid of the computer and computer like systems, gathering information

more quickly allows students to test predictions, make changes, and self direct their learning (NRC, 1996).

Technology changes our approach to the method of science study in the laboratory and classroom. Technology motivates and allows us to explore where we might only dream to explore. Using such equipment as CBL 2 makes learning more personal because the students take on the concepts; lessons like these form memorable events. The CBL 2 in some ways can be more than a model as it represents the real event. By gathering real data and experimenting using methods similar to original procedures, students can recreate established conclusions. A difficulty in the sciences that can be overcome with computer technology is that many of the ideas presented to students involve understanding and accepting events that happen on such a small scale. This is often the case when studying chemistry. Technology allows students to see the *unseen* (NRC, 1996).

Teaching with the aid of technical equipment can be motivational and bring about a new confidence in the teacher and the students. This technology is not just applicable for senior students. It applies to topics for lower grades and can provide the motivation needed by younger students. Students learn many of the ideas presented in history in a teacher directed format. Technology may be able to answer questions such as, how do we know that this is true? Technology has the potential to transform science education by creating the possibility for all students to access powerful technology and technology tools for exploration and analysis in a manner similar to scientists.

### *Terminology*

This section describes terms mentioned in the study.

**Hand-held technology:**

This term applies explicitly to graphing calculator technology and the data collection tools associated with graphing calculators.

**Data Collection Devices:**

This term applies to devices that when attached to the Texas Instruments graphing calculators through a Calculator Based Laboratory (CBL 2) unit create a laboratory environment where real-world data collection and graphic display may occur.

**Calculator Technology:**

Calculators referred to in this document are Graphing Calculators. In this research the calculators used were Texas Instruments model 83 plus (TI-83 plus).

**Probeware:**

Probes connected to data collection devices that allow the investigator to record temperature, pressure or other data.

## Chapter 2: Review of Research Literature

### *Introduction*

As discussed by Pea (1988) *educational technologies* can include methods, lessons, teachers, books, chalkboards, overheads, or any physical material. Historically, since World War II, the meaning has applied more strictly to include films and filmstrips, audiotapes, slide projectors, radios, and television. More recently, the term refers to computer-based learning such as interactive videodiscs, CD-ROMS, and computer communication technologies such as the Internet. The term *educational technologies* refer to the most advanced technology available for teaching and learning (Pea, 1988). After the launching of Sputnik on October 4<sup>th</sup>, 1957, it took less than one year for the U.S. congress to authorize expenditures of more than one billion dollars for a wide range of reforms and technologies to promote and develop programs and support individuals focusing in military defense and other areas (Dow, 1997). Funding made available during the Sputnik crisis created an opportunity to assimilate *educational technologies* into schools and classrooms.

Technology has the potential to change how we learn by making learning of the past more applicable. Effective classrooms combine traditional approaches with new approaches in order to facilitate learning the content and meeting the needs of the individual (International Society for Technology in Education (ISTE), 1998). Microcomputer Based Laboratory (MBL) equipment can now replace tedious and inaccurate methods for collecting data such as recording temperatures with thermometers and then plotting the points, or determining pH using bulky pH meters, often found in secondary science classes. To learn concepts generally taught in a teacher directed lecture

format teachers might use an exploration activity where students try different combinations, record results, and draw inferences from their own data. Technological devices can aid investigation by reducing student error during collection of data and allowing further focus on the ideas. These devices reduce the task of data collection; therefore, allowing the student to focus on the concept being examined. Technology in the form of computer aided designs, real world simulations, and modeling enhance the classroom (AAAS, 1989).

Any technology introduced into the public will come under scrutiny. What are its advantages, and disadvantages? Who benefits? Is this technology applicable to more than just one area? What about costs? What is necessary to learn this new technology? What are the negative side effects? Pea (1988) points out some draw backs for use and implementation of computer based technology in education. First, there is the sheer volume of different variations and applications that can easily overwhelm a teacher. Secondly, technology is expensive, and in order to keep up with rapid changes, schools need to invest large amounts of money and time in training. Technology is a long-term and costly commitment. Unfortunately, there is a large amount of technology that utilizes poor teaching techniques such as drill and practice, which promotes memorization instead of understanding. A third problem is providing proper in-service for teachers in order for them to learn how to implement technology into their teaching. Finally, although not an exhaustive list, there is the unfortunate aspect of using technology for the sake of using technology even if there is no educational value (Pea, 1998).

Television is a common form of technology that has made its way into the classroom. Neal Postman (1985) argued against the use of television in the classroom in

his book *Amusing ourselves to Death*. In the classroom students can ask questions and be active in learning; the television requires you to do nothing (Postman, 1985). We learn by doing. Like television, in some educational videos and computer based software we are asked to do nothing. However, one must not ignore technology. Technology is ubiquitous and in order to prepare for the future, we need to learn to use and apply technology in our daily lives. It is the responsibility of educators to find time and use for technology that uses inquiry based learning techniques. Providing questions that students can relate to and have personal interest in is one possible use for inquiry-based learning supported by technology.

#### *Authentic and Real World Science*

Dolin (2003) summarizes the definition of authentic science as being the incorporation real world problems into the classroom and adoption of characteristics used by research scientists to solve science based problems. Teaching science that is authentic is an increasing goal for educators. Edelson's (1998) research verifies this work for he found that numerous educational researchers had adopted authenticity as a major objective for learning. Students and teachers need to understand what science is in order to integrate its characteristics into the classroom and therefore be authentic.

Too often, science is just described as a series of steps that is progressively building on itself. This has been termed by Kuhn in his book *Structure of Scientific Revolutions* (1962) as "normal science". Normal science is gradual scientific development but growth of true scientific knowledge occurs in revolutions or "paradigm shifts". SFAA (1989) gives a much more dynamic and more fitting definition for science.

Science, mathematics, and technology are continually in flux—holding onto some ideas and ways of doing things, reshaping or discarding some, adding others. The time will inevitably come—sooner in some areas than others—when the recommendations will need to be revised to accommodate new knowledge (AAAS, 1989, Introduction: Recommendations, para. 20).

In this description of science, one visualizes that science is not, a continual stacking up of evidence but that in some situations when the evidence no longer supports the major ideas a change or revolution is necessary. Kuhn (1962) further supports the definition that science is not a linear sequential method but involves ideas and theories being reworked and reorganized with the understanding that no matter how well an idea can be explained, it is always subject to revision and therefore the production of a new theory.

A good model for learning about the process of science occurs in looking at topics of significant scientific events that occurred in history. Some of the most significant discoveries in science have resulted in paradigm shifts. For example, studying changes in the universe through the eyes of Ptolemy, Copernicus, and Kepler invite students to learn science and the process of doing science. In this example, there was gathering of evidence to support that the earth is the center of the solar system. Upon more discovery of evidence, a paradigm shift occurred and there was now acceptance of the sun being the centre of the solar system. History can help demonstrate science in terms of revolutions, for science ideas are always subject to modifications. Science never rests and is never satisfied with what it finds.

Too often one teaches subject material without relating it to how science occurs outside the classroom and rarely allows students to discover scientific principles for themselves. Halloun and Hestenes (1985) have uncovered evidence that shows that students are often unable to apply what they have learned in school. Authentic science involves working and teaching with material that is real and in some cases visual. Students are to have opportunities to gather and create their own data. Integrating technology and inquiry-based learning provides opportunity for students to perform learning that involves authentic and real world learning situations. Edelson (1998) concludes that many educational reformers since Dewey have been making science learning resemble science practice. This goal has some obvious benefits. Students move from being passive to active learners. Learning that involves data created by textbook authors can create passive learners but data created in front of students by students creates active and inquiring learners. Data collection is meaningful for the students if they themselves are collecting in a scientific and exploratory context. Authentic activities provide learners with the needed motivation to acquire new knowledge, incorporate the knowledge into their preconceived ideas, and see how they can apply it (Edelson, Gordin, & Pea, 1999). Authentic activities use real world data that is meaningful to the students and encourages students to model characteristics of research scientists such as observing, testing, refining procedures and reporting information. Students are to make better and more careful observations with greater accuracy and communicate their findings through graphs, charts, and in prose (AAAS, 1993).

*Benchmarks for Science Literacy* supports the idea of authenticity of the science process by stressing that science is not just about collecting knowledge about the world

for this does not necessarily lead to understanding science (AAAS, 1993). Science includes social aspects as well. Edelson (1998) believes that science is not just about investigation. He includes sharing results, concerns, and other questions with scientists in the community. Science becomes authentic when we integrate these attributes into the classroom. *Benchmarks for Science Literacy* recognizes the need for integrating the social aspect into science in order to make science in the classroom authentic and lists four aspects of the scientific enterprise: its social structure, its discipline, its ethics, and the role of scientists in public affairs and interests (AAAS, 1993). Through asking open-ended questions, integrating technology to create real world data, and having students pursue the social aspects associated with science, authentic learning can occur. The challenge is finding ways to integrate them so as to produce students that find the investigations fun, exciting, and meaningful to their personal lives.

There are many different methods for bringing the real world into the classroom using technology. One well-known series that utilizes learning through video is the Jasper series (1992) at Vanderbilt. This interactive program brings simulated real life problem solving situations into the classroom. Students work with the video to solve mathematical based problems such as purchasing a boat and taking it on a trip down a river (“Journey to Cedar Creek”), designing a safe playground (“Blueprints for Success”), or running a successful business (“Working Smart”). This series incorporates real world data, problem solving abilities, and pursues the goal of bringing real life situations into the classroom (Van Haneghan, Barron, Young, Williams, Vye, & Bransford, 1992).

### *Student-Centred Methods*

The National Research Council (1996) along with American Association for the Advancement of Science (1989) endorses changes in the practice of teaching science that increases public understanding of science. The reform document, the *National Science Education Standards* (NSES), funded by the National Science Foundation (NSF), acknowledges the need to use various different methods of instruction that are student-centered in order to promote the goal of scientific literacy. NSES emphasize inquiry as a new way of teaching and learning in order to understand the world (NRC, 1996). As early as the first part of the twentieth century, Whitehead's views on student learning reflected these ideas, as he stated, "let the main ideas which are introduced into a child's education be few and important.... The child should make them his own, and should understand their application here and now in the circumstances of his actual life" (Whitehead, 1929/1967, p. 2). Dewey (1964) condemns the traditional way of learning science and claims that science has suffered due to students being presented with ready-made data rather than letting the student use methods of inquiry to gain knowledge about the subject matter.

Too often, North American science classrooms do not encourage active learning. The usual high-school science "experiment" is unlike the real thing: The question to be investigated is decided by the teacher, not the investigators; what apparatus to use, what data to collect, and how to organize the data are also decided by the teacher (or the lab manual); time is not made available for repetitions or, when things are not working out, for revising the experiment; the results are not presented to other investigators for

criticism; and, to top it off, the correct answer is known ahead of time (AAAS, 1993, Chapter 1 Section B, para. 2).

The goal for fostering scientific literacy through inquiry-based learning is opposed to methods of learning similar to the ones mentioned above. The learning of science using traditional formats is not likely to produce students that are able to problem solve, and be able to develop understanding of science concepts. A more student-based approach, that encourages students to take an active role and to be more like scientists, is necessary and AAAS supports this idea (AAAS, 1989).

*i. Comparison of Different Student-Centred Methods*

Student directed teaching has many descriptors; however, all involve the idea that the student becomes active in his/her own learning. Terms such as discovery learning, inquiry-based, hands-on learning, constructivism, problem based learning, and the Learning Cycle all refer to various forms of student based learning.

Haury (1993) states that hands-on learning has links with inquiry because it is activity based instruction; however, just working with material and manipulating it does not classify the investigation as inquiry. He also mentions that discovery follows the ideas of the scientific method; however, the scientific method is too linear in its approach to problem solving and does not reflect the ideals of inquiry. When comparing inquiry to that of discovery learning and hands-on learning Haury (1993) states that neither are synonymous with inquiry. He is supportive of the definition of inquiry as stated by Novak (1964) “Inquiry is the [set] of behaviours involved in the struggle of human beings for reasonable explanations of phenomena about which they are curious.”

As mentioned by Sardilli (1998) other researchers refer to discovery learning, inquiry-based learning, and constructivism, as similar for they are science-based programs that focus on learning that is student based. Sardilli (1998) states that for this to happen the focus is to shift to the learner as being active in manipulation and experimentation and away from the teacher, therefore, decreasing the teacher's instructional time.

In general, most contemporary researchers in science education are supportive of inquiry-based learning (Shymansky, Hedges, & Woodworth, 1990). Haury (1993) reports research that inquiry-based learning programs enhance student performance, especially in graph interpretation and lab skills. He also reports improvement in science literacy skills in classrooms where inquiry related teaching has taken place.

#### *ii. Constructivism as a Form of Inquiry*

The constructivist's teaching approach emphasizes specific expectations for learning science. Constructivism is the process of finding information; findings become the content (Birshe, 1996). A science emphasizing process and de-emphasizing memorization is one aspect of the constructivist's idea for students' learning of science. SFAA (AAAS, 1989) supports the idea of promoting understanding rather than memorization of vocabulary. As well, NSES (NRC, 1996), is in support of this for they feel that teachers are to emphasize experiences, investigations, and thinking about explanations and deemphasize memorization of scientific terms and information.

In constructivism, students are to develop skills such as predicting results, observing, and drawing conclusion based on experiments that they actually perform. Some experiments may even simulate an actual experiment done by scientists in the past

and then include having the students draw similar conclusion for themselves. DeVries and Kohlberg (1990) describe constructivism as a method of learning in which the child is engaging in building his or her own knowledge and understanding. Applying prior knowledge to solve or investigate is vital in the constructivist form of inquiry-based learning. This form of inquiry-based learning stresses the idea of student ownership. Students using the inquiry approach would be rediscovering principles and as a result of their actions would remember the material, and find it more meaningful because they did it as opposed to being told about it by a teacher. The old principle ‘if you can do it, you understand it’ would be put into practice.

### *iii. Teacher’s Role in Inquiry Learning*

The teacher’s role for inquiry-based learning is different from that of a teacher directed lesson. From a teacher’s perspective, Colburn (2000) defines inquiry-based instruction as creating a classroom where students work on open-ended, student-centered, hands-on activities. Colburn further outlines several teacher tasks for creating an inquiry-based learning environment. Ask open-ended questions, encourage students to think for themselves, and avoid telling students what to do. In constructivism the approach is not teacher centered; the teacher facilitates scientific investigation by using many different strategies (Birshe, 1996). Jones (1999) points out that the curriculum is to have conceptual organization, to involve investigation and inquiry into authentic questions generated from children’s experience, to promote thinking and reasoning skills, and to involve application to real life. These ideas differ greatly from textbook and teacher directed formats for teaching and learning.

Abstract ideas need concrete situations. Support or rejection of student ideas on how something works or relates to something else relies on observations. Birshe (1996) finds that a child will accept findings after proving and verifying through personal discovery. A hands-on approach is fundamental in inquiry-based learning. Students are to manipulate materials, make changes, and record results. In other words students are to do real science and act as real scientists act.

Cooperative learning plays a part in student focused learning. Students are to work together in groups, combine their observation and predictions, share their ideas and help one another gain the necessary knowledge in order to succeed in science (Sardilli, 1998). Students are responsible for each other's learning and are to be supportive of one another. Reinforcement of good communication and group skills occur in this type of learning setting. One learns science by doing science. As students gain knowledge and experience, the investigations become for complex and students use concrete findings to reflect and further their understanding (AAAS, 1993). Scientific engagement calls for frequent hands-on activities. When the individual through careful and accurate observations discovers rules of science, the learning that takes place becomes powerful.

#### *iv. The Learning Cycle*

A good example of learning and teaching through inquiry is the Learning Cycle (Abraham, 1997). This method for learning and doing science is a good example of a method that integrates the attributes supported by all reform documents mentioned. The Learning Cycle has its origin in the Science Curriculum Improvement Study (SCIS) (Atkin & Karplus, 1962) and from the constructivist ideas and development theory of Jean Piaget (Abraham, 1997; Piaget, 1970). Barman and Kotar (1989) outline the three

distinct phases of Lawson, Abraham and Renner's (1989) approach. First, there is exploration. Students are encouraged to explore the new materials and make observations. Second, there is concept introduction. As a large group, there is discussion, organization of observations, vocabulary introduction by the teacher, and then other material provided to reinforce the investigation of the concepts. The final stage is concept application. The teacher provides a new situation or problem for the students to apply the new concept and additional hands-on activities are performed to reinforce the concept. These ideas are similar to Whitehead's *Play, Precision, and Generalization* (Whitehead, 1929). The inquiry-based approach to learning is not a new idea but has great value for empowering students with science literacy. Through this approach, and combining it with the technology available today, students have the opportunity to learn in a meaningful and productive manner.

### *Microcomputer Based Technology*

The use of microcomputers in science teaching as a laboratory tool for collection and analysis is one of this technology's most powerful uses (Krajcik & Layman, 1992). Microcomputers are important and useful instruments for the development of a student's science literacy skills such as problem solving. Microcomputers may even strengthen students' ability to improve graphing and interpretation skills (Linn, Layman, & Nachmias, 1987). One specific type of Microcomputer Based Laboratory (MBL) is that of the Calculator-Based Laboratory (CBL). Wetzel reports finding that CBL and probeware improves teaching and learning for it engages students' higher order thinking skills (Wetzel, 1999).

Another finding reported by Wetzel (1999) is that this form of technology (MBL and CBL) is simple, useful by various grade levels, and different cognitive abilities within same grade levels. His research states that learning using CBL equipment levels the educational playing field creating equal opportunities for all students, an idea supported by AAAS. Along with leveling the educational playing field, technology can be motivational. Much research has presented evidence that demonstrates being motivated results in better attitudes, in turn improving achievement (Ruddock, Sturman, Schagen, Styles, Gnaldi, & Vappula, 2004).

It is important for students to be able to simulate the experience of acting like scientists. In Project 2061's, *Benchmarks for Science Literacy* there is acknowledgement of importance for computers. AAAS believes that students are to use computers as scientists use them- for collection, storage, and retrieval of data, to help in data analysis, to prepare tables and graphs, and to write summary reports (AAAS, 1993). The MBL provides the genuine scientific experience for students and aids them in constructing science concepts using an inquiry-based format (Mokros & Tinker, 1987).

Microcomputers, when connected to various probes, provide a way of collecting, recording and graphing data. The term probeware describes the various probes attached to a MBL during data collection. Some of the probeware include detecting and measuring motion, temperature, pH, gas pressure, light, sound, and force. The data can be transmitted to a computer, graphing calculator, or be stored for later use. Often display of data collection in real time allows students a greater appreciation of what graphed data really signifies. Thornton and Solokoff (1990) report five ways that MBL technology is important for student learning. First, equipment enables students to avoid time-

consuming tasks of data collection and display. Second, students can get data in real time, thus providing immediate feedback. Third, since data collection is quick, the opportunity for revision and retesting is possible. Fourth, equipment is generally not complicated requiring students less time for learning how to use the equipment and more time to focus on the experiment and concept. Finally, since equipment is easy to use, a wide range of students from elementary school to university can use the equipment to investigate their world.

Krajcik and Layman (1992) also stress the importance of real time data collection being one of the key elements in helping students construct science concepts and improve graphing skills. This is because the technology provides opportunities for students to connect the production of the graph with the physical manipulation of the materials. They also state some of Brasell's (1987) work that concluded that a small delay (20 – 30 minutes) in graph production could hinder students' concept development. The graph is not a static entity because the students are watching its production (Linn, Layman, & Nachmias, 1987).

As a result of easy set up, students may perform more experiments as microcomputer-based laboratory tools are quick and easy to use and make repetitions of an experiment, with slight variations each time, easy to do (Krajcik & Layman, 1992). Changes provide opportunities for more simulation runs and data collection. This method of performing experiments, not only simulates the true essence of science, but also the understanding necessary for learning of a concept. Students have an opportunity to select conditions, make mistakes and problem solve. The experiment becomes more meaningful as students may have a better attitude towards his/her learning because of being involved.

Some researchers report that students are more willing to replicate, to evaluate and improve the experiment because of the ease of the MBL technology (Krajcik & Layman, 1992). Most MBL packages have a function of printing out graphed data allowing students an opportunity to include the graphs in reports and discuss the data's significance later.

Graphs in science and mathematics summarize relationships and present data in a readable form. Ozgun-Koca (2001) reports that being able to interpret or construct graphical representations is a crucial skill for students pursuing careers related to science and mathematics. Also in this article are findings by Janvier (1981) stating that students have problems interpreting graphs and it is rare to study meaning and graph interpretations. There is a lot of research that applies to improving students' ability in the area of graph interpretation, analysis, and many researchers advocate the use of computers, calculators, Microcomputer-Based Laboratories (MBLs) or Calculator-Based Laboratories (CBLs) (Ozgun-Koca, 2001). Mokros and Tinker (1987) in a longitudinal study have shown significant student gain in the understanding of graphing concepts by teaching science topics, not by specifically teaching graphing skills. One of their reasons for such findings is that MBL technology eliminates the need for tedious graph production. Oakes' (1997) research even suggests that combining discovery teaching with graphical skills in science instruction can allow students to rediscover the laws and rules of nature rather than just see them as an equation for plugging in data.

Not only has MBL technology great potential for teaching students, but teachers can benefit as well for they recognize the role of personal experiences with conceptual change (Layman & Krajcik, 1992). However, student understanding of science using

MBL technology has its limitations. One such limitation is the teacher's ability to use the technology. The teacher plays a pivotal role in creating an atmosphere that allows students to investigate and the technology's effectiveness depends on the teacher's understanding of how to use the new technology (Krajcik & Layman, 1992). Although teachers have substantial access to instructional technology for classroom use, research has found little evidence that they are systematically employing this technology (Wetzel, 1999).

### *Inquiry Based Learning and Technology*

Recently there have been increasing numbers of recommendations to promote inquiry-based learning in science classrooms (AAAS, 1989). A major reason for this is that science is not static and sequential but is rather dynamic in nature. In order to do true science, one is to ask open-ended questions and combine this with personal experience and new knowledge. Science is to be meaningful and simulate the activities of true scientists in the field. Bringing together the trend of inquiry learning and combining it with technology that is easy to use for high school students brings about exciting possibilities. Edelson, Gordin, and Pea (1999) state that computer technologies are receiving increased attention from the science education community because of their potential to facilitate teaching from inquiry. Technology combined with inquiry-based learning has been used in the Earth sciences (Edelson, Gordin & Pea, 1999), physics (Bernhard, 2000), and other areas of science (Wetzel & Varrella, 2000).

Computer based technology provides unique opportunities for students to engage in inquiry-based learning. Blumenfeld, Soloway, Marx, Krajcik, Guzdial, and Palincsar (1991) outline several ways that technology can contribute to the learning process. They

state that technology enhances interest and motivation, provides access to information, allows students to actively store and manipulate how data can be represented, do complex calculations, and perform diagnosis and error correcting.

Technology provides great opportunities for students to investigate science through inquiry-based learning. However, there are some challenges to overcome in order to integrate technology and inquiry learning successfully. Edelson, Gordin, and Pea (1999) highlight five challenges:

1. Inquiry learning is to have meaningful presentation. In order for inquiry to take place, students are to be sufficiently motivated. Inquiry learning requires learners to be more motivated than traditional ways of learning science material. In order for students to be motivated, it is important for them to have a legitimate interest in what is going on in the classroom.
2. Students are to be able to perform the tasks that are necessary in order to do the investigation. Data collection for scientific investigations and analysis can be complicated. In order to obtain data for learning concepts, data production has to occur with a certain level of precision. Students need to master the necessary skills in order to benefit from their investigations.
3. Formulating research questions, developing a procedure, designing methods to collect data, being able to interpret data to obtain the required content are high order thinking skills. Lacking these competencies hinders the investigation.
4. Open-ended questions require organizational and management skills. Traditionally students do not have these skills. Investigating questions that utilize inquiry may require long periods in order to properly and sufficiently answer the

questions. If students do not have the necessary management skills it is difficult for them to be engaged in open-ended inquiry.

5. Open-ended inquiry learning has to fit into the constraints of the learning environment. Time spent in classrooms is generally fixed and can be restricting. The practicality of being in a classroom may cause inquiry learning to fail. What technology is available and how readily available are factors that help determine learning of this style. Not all schools can afford the equipment that is necessary for certain investigations. Functioning within the setting of the school can hinder inquiry learning that uses technology.

Although the difficulties faced by learning using inquiry-based methods and technology are legitimate and serious concerns, Edelson, Gordin, and Pea (1999) have outlined a variety of technological and curricular strategies for dealing with the shortcomings discussed. Investigation problems are to be meaningful and matter to the students (Barron et al., 1998). Beginning activities involving technology are to be structured; introduction is to be slow and careful. Some activities may lead up to the open-ended questions asked to the students. The students can then use the activities as prior knowledge. Information sources that provide resources describing the investigative tool use in other experiments can also provide the necessary support needed by students.

Teachers who integrate technology into their classroom have been termed *high tech* teachers as reported by Wetzel (1999). He reports findings by Honey and Moeller (1990) that these *high tech* teachers tend to be more student-centered, employ hands-on, inquiry-based methods, and have collaborative learning strategies in their classrooms. Conversely, teachers categorized as *low tech* tend to be more diverse in their teaching

strategies. They used some student-centered approaches but were more teacher directed and feared that integrating technology into their classroom would reduce their authority in the classroom. Further studies by Dexter, Anderson and Becker (1999) categorize teachers as substantially constructivist, weak constructivist, or non-constructivists. They define a substantially constructivist teacher as one that uses student-centered learning and successfully integrates technology. In most cases in order to integrate technology, the teacher pedagogy will need to change (Wetzel, 1999). As will be stated, some research has provided evidence that teachers are not willing to change their methodology making the goals of increasing scientific literacy difficult to accomplish. Unfortunately, the reform is destined to fail unless teachers move beyond the status quo (Bybee, 1993).

The research supports the use of MBL technology and inquiry-based learning methods. Thorton and Solokof (1990) reported that having the students make predictions and then test them enhanced the students' learning of that concept. Murphy (2004) reports evidence presented by Russel, Lucas, and McRobbie (1999) that the linking of familiar learning strategies such as Predict Observe and Explain (POE) to technology enables students to learn in effective ways. MBL technology enhances inquiry-based learning methods but involve the teacher being comfortable and confident in using the technology. The question of, what if? is likely to come up and the teacher will need to be able to guide students in order to help them make good choices for experimental design that will enhance the learning of concepts that are being studied.

### *Integrating Science and Mathematics using Technology*

In most cases, schools organize their curriculum into distinct subject areas. This separation of subject areas is further observed as students move into higher grades for

there is even further division within a given subject area. Schools in British Columbia divide their senior science into biology, physics, forestry, Earth science, and chemistry. Wicklein and Schell (1995) state that it is a poor assumption that students will connect their school knowledge and apply it in context outside of the classroom. Wicklein and Schell (1995) also report research that gives evidence that this is not the case. Senge (1990) outlines the concern when one fragments to make concepts more manageable. He mentions that by doing so we lose the connection of the smaller parts to the larger whole. Connections to other areas are of great importance. Learning cannot be done in isolation. There is to be a constant awareness of how what one is learning affects and applies to other subject areas.

Society has become technological and people need to be able to integrate math, science and technology in order to improve their lives, lives of those around them, and to become competitive in the work force (Lankard, 1993; Toffler, 1970). SFAA believes that the science-literate person is one who is aware of the dependency between science, mathematics, and technology (AAAS, 1989). SFAA states the United States, a prosperous nation that claims to value education, is to feature schools that integrate science, math, and technology for all students (AAAS, 1989). In everyday life math, science, and technology are not separated but are used together to solve problems. For as Whitehead has observed, “there is only one subject matter for education, and that is life, in all of its manifestations” (Whitehead, 1929, p. 6-7) Therefore, in order for students to be able to function in the 21<sup>st</sup> century students will need to learn that math, science, and technology are not stand-alone subjects.

One of the growing trends in education is the integration of subject matter such as math, science, and technology commonly called MST (Foster, 1994). Foster (1994) provides a lot of evidence supporting the need for MST. He acknowledges many researchers, associations, journals, and conferences as being advocates for integration of these subjects. A major association is that of the International Technology Education Association (ITEA) and their journal, *The Technology Teacher* (TTT), reflects support for integration of science, math, and technology.

One cannot have scientific inquiry without using mathematics as a tool for analysis. Science provides the problems for mathematics to investigate and mathematics provides science with powerful tools to analyze data collected (AAAS, 1989). There is also a lot of motivation to study math and science when real world problems are involved. When studying real world problems, you need to apply principles of mathematics to understand fully what you are studying. By not integrating math into science, an incomplete understanding of the investigation may result.

Another reason for integration is that science provides rich examples for demonstrating mathematical relationships and practical applications for mathematics taught in school curriculums. Graphing of data generated through investigating scientific phenomena, determining 'lines of best fit', correlations of two variables, and relating the concept of slope are but some of the areas where mathematics can be taught while being integrated into science. In many of these areas, technology is very useful for gathering data for mathematical analysis. Lankard (1993) has reported that new technologies have increased the importance of science and math knowledge by generating an increase in varied application of the scientifically based material. New technologies such as MBL

and CBL technology validate these findings. These new technologies provide even easier methods for students to explore and use inquiry-based learning methods to not only learn about science but also see the value of mathematics.

It is necessary for teachers to learn the value in integrating math, science, and technology. Basista and Matthews (2002) state teachers need to experience science and math integration so that they will be more likely to teach integrated curricula in their classrooms. Basista and Matthews continue by stating that there are many opportunities such as summer institutes, academic year support activities, and other workshops for learning about integration of these different subject areas. Basista and Matthews also report that after participating in these programs, teachers had a better understanding of how to integrate math and science. NSF has funded several integration projects such as the Materials Technology program (Lankard, 1993). In this program, staff was to work with materials in a lab or industrial setting first before teaching that involved cooperative learning techniques. Some of the benefits were that teachers improved their teaching skills, and became more enthusiastic and motivated. Circumstances such as these serve to reinforce the necessity of integration of different subject areas.

### *Conclusion*

In summary, the literature has provided evidence that student based learning methods are beneficial for deeper understanding of science. Technology provides motivation, opportunities for authentic learning, and for understanding the process of science. Today's technology makes integration of technology and student based learning methods possible. Science literacy may be improved by having students spend less time

on collecting data and more time thinking, analyzing, and applying the data to solve problems.

Much of the research stated in this text is in response to reform literature written with respect to the needs of the U.S. Given that there are many differences between the U.S.'s educational system and Canada's (for example: the U.S education system is more localized as compared to a more centralized system here in Canada (Gronlund & Cameron, 2004)) it is necessary to provide research that is founded in Canada. This study provides research that documents evidence that is in support of Canadian reform changes supported by the Pan Canadian Framework (1995).

## Chapter 3: Method

### *Research questions*

The purpose of this research was to attempt to examine the role of CBL 2 technology in promoting guided inquiry based teaching methods. Inquiry characteristics include teacher-student collaboration, Learning Cycle characteristics (Atkin & Karplus, 1962), student planning of investigations and activities, concepts emerging after exploration, and class discussion and debate. A second purpose was to assess conceptual changes in students' abilities to read data from graphs, calculate slopes, Y-intercepts, interpolate, and extrapolate data.

The study design attempted to answer the following questions:

Research Question One (RQ1): Does hand-held technology, CBL 2, help promote guided inquiry, hands-on based teaching methods? If so, to what degree?

Research Question Two (RQ2): Does the use of hand-held technology, CBL 2, help improve student graph interpretation skills?

This chapter outlines the method for the pilot and research study, from this point known as the study, and documents revisions made to the research method in order to improve data collection and teaching for the study.

Prior to the start of the pilot and study, the researcher followed the necessary ethical procedures outlined by the University of Victoria. The researcher outlined all research that involved students and protocols for working with students were developed. Participants and parents/guardians signed a letter of consent prior to the start of the research (Appendix E contains consent letter).

The pilot and study were a quasi-experimental two group (one experimental, one control) research design and utilized quantitative and qualitative methodologies (Gall, Gall, & Borg, 2005). Groups for the pilot were two intact grade-eleven chemistry classes from an urban city school in Western Canada. Students in grade-eleven have the option to choose chemistry as one of their required grade eleven-science courses. (Other options at this school are biology, physics, and Earth science). Twenty-six students participated in the control group with an equal number of gender distribution. Regarding class composition for the experimental group, there were 19 students, 13 of whom were female and six were males. The study groups were two intact grade-eight science classes from the same school as the pilot. Students in grade-eight must take a general science class that incorporates science principles from physics, biology, chemistry, and Earth science. Twenty-three students participated in the control group, 10 females, and 13 males. In the experimental group, there were 26 students, 16 females, and 10 males.

The researcher created and taught a guided-inquiry and traditional unit for grade eight science that followed Prescribed Learning Outcomes (PLOs) prescribed by the British Columbia Ministry of Education on the topic of heat energy. The following list of PLO's involved content and skills specifically used in the lessons (Government of British Columbia. Ministry of Education, 2004):

Expectations are that students will:

- demonstrate and explain different methods of energy transfer and relate them to daily life.
- demonstrate and explain how basic concepts relating to heat are used in common applications.

- plan appropriate procedures to test hypothesis and predictions.
- use graphs and simple statistics to analyze data.

use information and conclusions as a basis for further comparisons, investigations, or analyses.

Although the lessons prepared for the actual research study were for grade-eight students, it was appropriate to pilot them with grade eleven students for several reasons. First, due to the size of the school, there were no other grade eight-science classes for piloting purposes. Second, these chemistry students were from the researcher's own classes; therefore, there would be minimal disruption for other teachers. A third reason was that piloting with older students gave the researcher many opportunities to ask for student input for refining the research questions and methods as well as smoothing out potential difficulties with the technology. Finally, the material in this research is in alignment with some of the objectives in the B. C. curriculum for chemistry students; therefore, it was valid to teach these lessons to the researcher's grade 11 students.

Assignment of the students was predetermined due to timetabling constraints at the school level and hence was not random. However, a random number determined selection of the experimental group. The researcher chose one class from the pilot and one class from the study, generated a single random number from one to ten on a calculator, and if an odd number was generated those classes became the experimental, else they were the control classes.

Conducting a pilot study greatly aided the refinement of the research. During piloting, the researcher created a journal and at the conclusion of the pilot undertook a

process of action research in order to refine the lessons and instructional practice (Gall, Gall, & Borg, 2005).

The pilot occurred in the fall of 2004 and lasted for seven continuous classes. The study occurred in the winter of 2005 and lasted for eight days. There was an average of 70 minutes of instruction per class. The addition of one class period to the study resulted from findings from the pilot. Creating a pre-lesson helped to reduce student anxiety in the experimental. Teaching of this pre-lesson was prior to the Day 1 lesson and used CBL 2 technology with minimal new science content. The control class learned the same content on that day but from a traditional perspective with no CBL 2 technology. The pre-lesson gave a *running start* to both classes making learning the content more manageable.

There was strict following of lesson plans for both control and experimental groups in order to reduce any potential bias, given that the researcher was the teacher for both groups (see appendix A for all lesson plans). All assignments, evaluations, and even teacher enthusiasm in both groups were paralleled. The two major differences between the control and experimental classes were learning methods and use of technology. The research took great care to cover the same subject matter in both groups.

### *Control Group*

Students in the control group did not use CBL 2 technology. In the control group, the teacher employed a more traditional instructional approach. Students in this group covered PLOs by taking notes, answering questions as individuals, and by performing prepared *recipe style* experiments designed by the teacher or textbook. The teacher created all data examined by control classes prior to the start of the class and any in-class experiments were teacher demonstrations. Exceptions were lessons “Day 1” and “Day 6

& 7” (see Appendix A). Utilization of similar approaches in the past resulted in positive affective behaviours; therefore, exceptions were reasonable. The researcher made efforts not to teach the control group using an approach that might deter students from enjoying science. The traditional teaching method utilizes less interactive and thought provoking techniques. To compensate, the researcher taught control classes with enthusiasm, and effort to maintain student interest. The traditional approach used was very similar to teaching methods used by the majority of science teachers in that school and district (if not, all of B.C.). In the control group, there was production of hand drawn paper and pencil graphs when required and ‘lines of best fit’ and calculation of slopes. In addition, interpolation and extrapolation of data from graphed material aided in answering questions posed in lessons.

### *Experimental Group*

Students in the experimental group learned science from a guided inquiry hands-on perspective and used CBL 2 technology. Students in this group covered prescribed learning objectives by investigating questions presented by the teacher, having the teacher probe students for prior knowledge, and produce problem solving methods through class and group discussion. All data were collected using CBL 2 technology along with various appropriate probes such as temperature and pressure sensors. In the pilot, students created a computer print out of their collected data for each group of three students. In the study, students created computer printouts of collected data for each individual student in the subgroup. Students drew ‘lines of best fit’ and calculated slopes by hand. Although it took longer to get data to each individual student, because there were more printouts, it was necessary after noting observations in the pilot. In the pilot it

was noticed by the researcher that if one print out was provided for the group, one student dominated the group and did all ‘lines of best fit’ and calculated the slopes. This change avoided the problem and allowed all students opportunities to work with graphed data. There was interpolation and extrapolation of data from the graphs in order to answer experiment questions that arose as part of the ongoing instruction. In the experimental group, the content, assessments, and environment were as much as possible identical to what took place in the control group with the one important difference; use of technology-based strategies.

Texas Instruments (TI) provided the following equipment for study: CBL 2, TI-83 *plus* graphing calculators, temperature and pressure sensors. Graphical Analysis developed by Vernier displayed and printed collected data.

### *Subgroups*

There was creation of subgroups with a maximum of three students per subgroup for both experimental and control groups. The researcher used these subgroups in all inquiry explorations using CBL 2 technology and in any other group work for the experimental class. Subgroup use for the control was only for journal writing purposes. There was creation of random subgroups by numbering the students from one to the maximum number appropriate for that class. For example, the pilot study contained 19 students so the researcher numbered students from one to seven. Once numbered, those students designated as a “1” created subgroup one etc..., thus creating subgroups with a maximum of three students per group. Use of subgroups created in the first exploration continued throughout the research classes.

*Qualitative data*

Qualitative data collected for the study focused on providing information to answer: Research Question One (RQ1): Does hand-held technology, CBL 2, help promote guided inquiry, hands-on based teaching methods? If so, to what degree? Students in both experimental and control groups wrote daily journals at the end of every class (except the pre-lesson, in the study). Journal writing stemmed from three prompts presented at the end of each lesson (see Appendix C for each day's journal prompts). In each group of three journal questions, one prompt was a low-level knowledge based question, one was a medium level question, and a third was a high-level based question. Designation of levels was according to Bloom's taxonomy (Bloom, 1956). Questions for journaling were classified by the researcher and four other teachers, in order to reduce possible bias and to increase the classification validity, using a rubric modified from the Galileo Educational Network Association (GENA, 2002). Journal writing, for both control and experimental classes occurred in their predetermined subgroups and served as a line of communication between teacher and student (Piburn & Middleton, 1997). As a subgroup, students collectively picked one of three questions to answer. Students discussed the chosen question and method(s) of answering and then individually answered the question in their daily journal, using the heading "Day 1", etc..., that corresponded to that lesson day.

Interviews were of a semi-structured protocol (Gall, Gall, & Borg, 2005). In the pilot, only two control and two experimental students were interviewed. Pilot interviews were not analysed in detail. Instead, they provided an opportunity for the researcher to refine and practice techniques of interviewing students. For the study, the researcher

conducted interviews with eight students, four students from each group. With cooperation of the regular teacher, the researcher chose students. This cooperation with the regular teacher was necessary in order to ensure a wide range of student abilities. Interviews were with two higher ranked and two lower ranked students from each group. Creation of rankings came from averaged marks obtained during the semester's work. Some interview questions proposed problems for students to solve and some asked students to reflect on why they did better on post-test questions as opposed to pre-test questions. (See Appendix B for interview questions). These methods provided insight and evidence used to answer Research Question One.

### *Quantitative data*

Collection and analysis of quantitative data provided answers for addressing Research Question Two (RQ2): Does the use of technology, CBL 2, improve student graph interpretation skills? A neutral third party administered two pretests and posttests in order to measure improvement in graph interpretation skills. The first test was the Graphing Interpretation Skill Test (GIST) developed by Svec (1999) (see Appendix D). This test contains 12 multiple-choice items and focuses on identifying misconceptions and difficulties in graphing identified in other studies using similar multiple-choice tests (Svec, 1999). The GIST (1999) was field-tested by Svec (1999) and had a KR-20 of 0.97. A second test, the Test of Graphing in Science (TOGS) developed by McKenzie and Padilla (1986), combined graph construction and interpretation and contained a combination of 26 multiple-choice items and had a KR-20 of 0.83 (McKenzie & Padilla, 1986). Twelve multiple-choice items of the 26 questions applied to graph interpretation and had a reliability of 0.73 (KR-20) (McKenzie and Padilla, 1986). McKenzie and

Padilla's (1986) research demonstrated that the TOGS (1986) was a reliable instrument for measuring graphing abilities. There was addition of five multiple-choice questions to the 12 for the pilot and three additional multiple-choice questions for the study. These additional questions provided information to the researcher in areas of graph construction such as drawing 'lines of best fit' for plotted data. However, after examination of the 17 question test used in the pilot, the researcher decided to remove two of the five-graph construction questions for they were not appropriate or applicable to the types of graphs constructed in any of the lessons. This reduced the TOGS (1986) to 15 questions (see Appendix D). Construction based concepts were addressed during the lessons and provided information to the researcher but were not pertinent to the research questions. The GIST (1999) and TOGS (1986) were especially useful for this project since they dealt with the intended graph interpretation skills taught in lessons during the research study. These skills were ability to read graphed data, to calculate slopes and Y-intercepts, and to interpolate and extrapolate data.

Both groups wrote the GIST (1999) and TOGS (1986) as pre and post-tests. A pretest-posttest method explored the comparability of the groups and measured growth in understanding of graph interpretation skills. A minimum of 30 days occurred between administration of pre and post-test in order to reduce test-wiseness. A neutral third party administered and coded all tests in order to protect the anonymity of those participating.

### *Data Analysis*

The researcher first sorted journal responses for the control and experimental groups into their low, medium, or high level of cognitive complexity. There was further categorization of each response, correct or incorrect, thus creating six possible categories.

The researcher scored student journal responses with a value from one to six for data display purposes (see Table 3.1). There was a comparison between experimental and control groups with respect to the number of students from each group answering responses correctly and percentages of students in each group that chose low, medium, and high inquiry items.

Table 3.1

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**Classification of Journal Responses**


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Low inquiry	Score 1: Incorrect
	Score 2: Correct
Medium inquiry	Score 3: Incorrect
	Score 4: Correct
High inquiry	Score 5: Incorrect
	Score 6: Correct

---

From student interviews, the researcher used anecdotes that were applicable to the answering of the research questions. The following format displayed the data: question asked followed by responses from students. The researcher then noted insights reflecting similarities and differences between the two groups. For interview questions asked, the researcher used only two student responses, one high rank and one low, from each of the two groups. Those students chosen represented the clearest responses to questions asked.

Quantitative data together with the qualitative data helped to answer Research Question Two. SPSS version 13.0 performed all statistical analysis computations such as descriptive statistics and paired and independent *t*-tests. All *t*-score values came from a critical values table for two-tailed scores (Howell, 2004). For all *t*-tests analyses, two-

tailed testing was deemed appropriate for the researcher was interested in determining significance of improvement (or possible lack of improvement) for each group from their pre-test scores to post-test scores. The researcher chose an alpha level equal to 0.05 as the level of significance (Gall, Gall, & Borg, 2005).

In order to display changes from pre-test to post-test for each item on tests a scatter plot of  $p$ -values (proportions of students getting item correct) was created. Finally, there was a percentage based comparison of student improvement from pre to post-test focusing on group and individual scores for all tests items and then on high inquiry items. The researcher and four other teachers classified items on the TOGS (1086) and GIST (1999) as high and low inquiry by using a rubric modified from the Galileo Educational Network Association (GENA, 2002). Table 3.2 shows extent of agreement of other teachers with the researcher's classification.

Table 3.2

## Classification of TOGS and GIST test along with third parties' agreement

Item #	TOGS (15 items)	Percent agreement	GIST (12 items)	Percent Agreement
1	Low	100	High	75
2	Low	100	High	75
3	High	50	High	100
4	Low	50	Low	100
5	Low	100	High	50
6	High	50	High	75
7	Low	100	High	75
8	Low	50	Low	100
9	High	75	Low	100
10	Low	100	Low	100
11	High	75	Low	100
12	High	100	High	100
13	High	100		
14	High	75		
15	High	75		

For the pilot study, only the GIST (1999) data were quantitatively analysed. The reason for this was due to a shortening of the TOGS (1986) test from 17 to 15 items and therefore the two tests administered in the pilot and actual study were different.

## Chapter 4: Data Analysis

This chapter focuses on data collected to answer the research questions and provides the following evidence.

- Pilot study evidence of the student's cognitive improvement in interpreting graphed material because of content facilitated by instructional uses of technology and measured using an achievement test.
- Pilot study evidence of guided inquiry learning facilitated by hand-held technology demonstrated by student journal writing.
- Research study evidence of the students' cognitive improvement in interpreting graphed material because of content facilitated by instructional uses of technology and measured using an achievement test.
- Research study evidence of guided inquiry learning facilitated by hand-held technology demonstrated by student interviews and journal writing.

### *Pilot Study Data Analysis*

#### *Descriptive statistics*

The answering of Research Question Two (RQ2): Does the use of hand-held technology, CBL 2, help improve student graph interpretation skills, began with GIST (1999) pre and post-test pilot data. See Table 4.1 for the control group descriptive statistics results that compare pre to post-test scores. The pre and post-test measures of central tendency were very similar and focused around 6 for the pre-test and 7 for the post-test. Since all measures of central tendency were around the same value, there was comparison of only mean values. Control group averages did increase, 55% to 60%.

However, the standard deviations from pre and post were similar indicating that the spread of the scores did not change.

Table 4.1

Control Group Descriptive Statistics (maximum score = 12)

	Pre-test	Post-test
<i>M</i>	6.65	7.15
<i>Md</i>	6.0	7.0
<i>SD</i>	2.43	2.49
<i>N</i>	26	26

Corresponding gains for to the experimental group from pre to post-test were 58% to 65% (see Table 4.2). Again all values of central tendency, pre and post, were relatively similar; therefore, any comparisons involved just means. Experimental student mean values increased. However, the greater standard deviation in post scores indicate that some students scored higher and some lower as compared with the pre-test. This suggests the existence of some instructional effect in the experiment group. To determine if improvement in any of the groups were significant, *t*-test analysis was necessary.

Table 4.2

## Experimental Group Descriptive Statistics (maximum score = 12)

	Pre-test	Post-test
<i>M</i>	7.00	7.84
<i>Mdn</i>	7.0	8.0
<i>SD</i>	2.08	2.75
<i>N</i>	19	19

*t*-test analysis

Comparison of means from pre and post-test scores for control students using a paired *t*-test are in Table 4.3. The difference in means between the pre and post-test for the control group was not statistically significant,  $t(25) = -1.060, p > 0.05$ . Results from comparing means from pre to post-test for the experimental group using a paired *t*-test are in Table 4.3. For this group it was determined that, the experimental group had not improved a significant amount  $t(18) = -1.323, p > 0.05$ .

Table 4.3

Control and Experimental Group Paired *t*-test

Source	<i>N</i>	<i>M</i>	<i>SD</i>	<i>SE</i>	<i>T</i>	<i>Df</i>	<i>p</i>
Control	26	-.50	2.40	.47	-1.060	25	> 0.05
Experimental	19	-.84	2.77	.63	-1.323	18	> 0.05

Conduction of an independent *t*-test comparing control and experimental means was necessary to determine the similarity between the two groups for the GIST. Table 4.4

has the results. From the  $t$ -statistic score it was concluded that difference between the control and experimental groups were not significant  $t(43) = .500, p > 0.05$ . A similar test compared post-test means; the  $t$ -statistic also indicated that the means were not significantly different  $t(43) = .875, p > 0.05$ .

Table 4.4

Pre and Post-test Independent  $t$ -test for GIST

Source	$N$	$M$	$SD$	$SE$	$T$	$Df$	$p$
Pre-test					.500	43	> 0.05
Post-test					.875	43	> 0.05

*Instrument Item Analysis Based on Group Averages.*

To investigate group changes from pre to post-test with respect to individual test items, the researcher made a scatter plot post-test vs. pre-test for both the control and experimental groups. The data plotted shows the item difficulties as the proportion (percentage) of students getting those items correct. Resulting data showed that the control students as a group improved from pre to post-test on five of 12 items, 42% (see Figure 4.1). Figure 4.2 compares post-test vs. pre-test for the experimental group. Resulting data showed there was improvement in seven out of the 12 items, 58%. Further analysis using these two scatter plots but investigating changes in high inquiry items shows that in the case of control students there was improvement in three out of seven, 43% (see Figure 4.1) but for experimental there was improvement in four of the seven high inquiry items, 57% (see Figure 4.2).

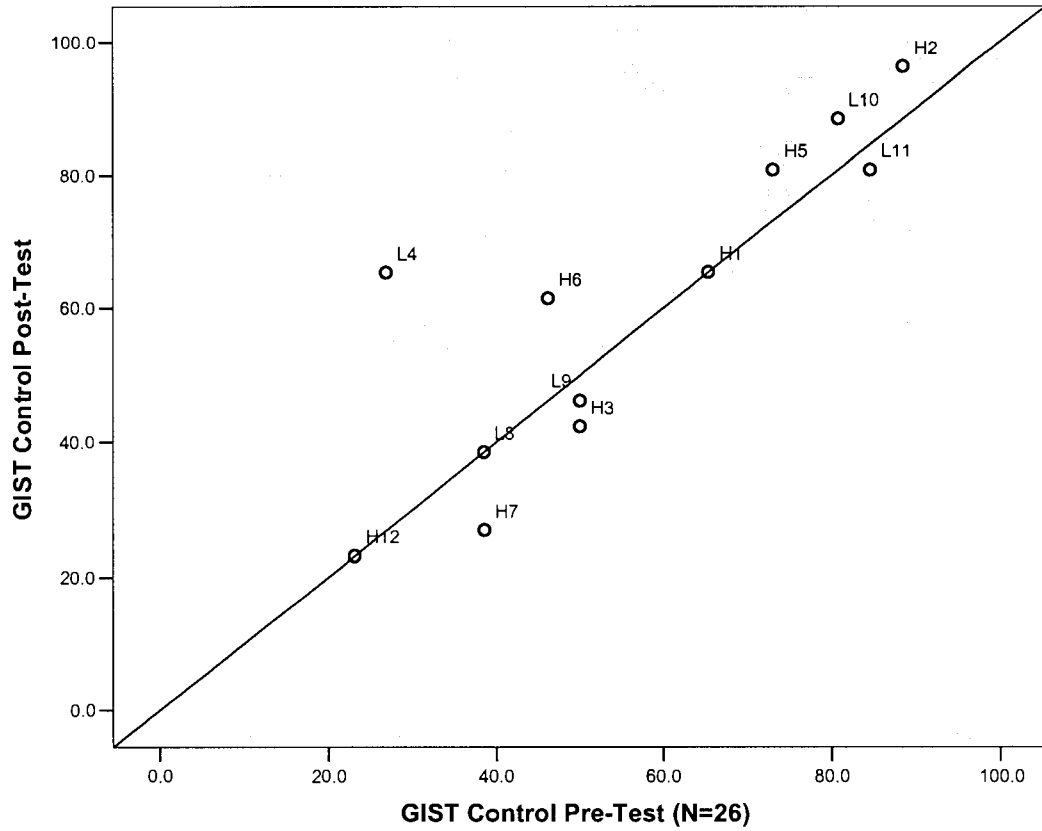


Figure 4.1: Item-level change from pre to post tests for GIST (pilot): Control Group. H = high inquiry, L = low inquiry. (Axes show percentages of students getting item correct.)

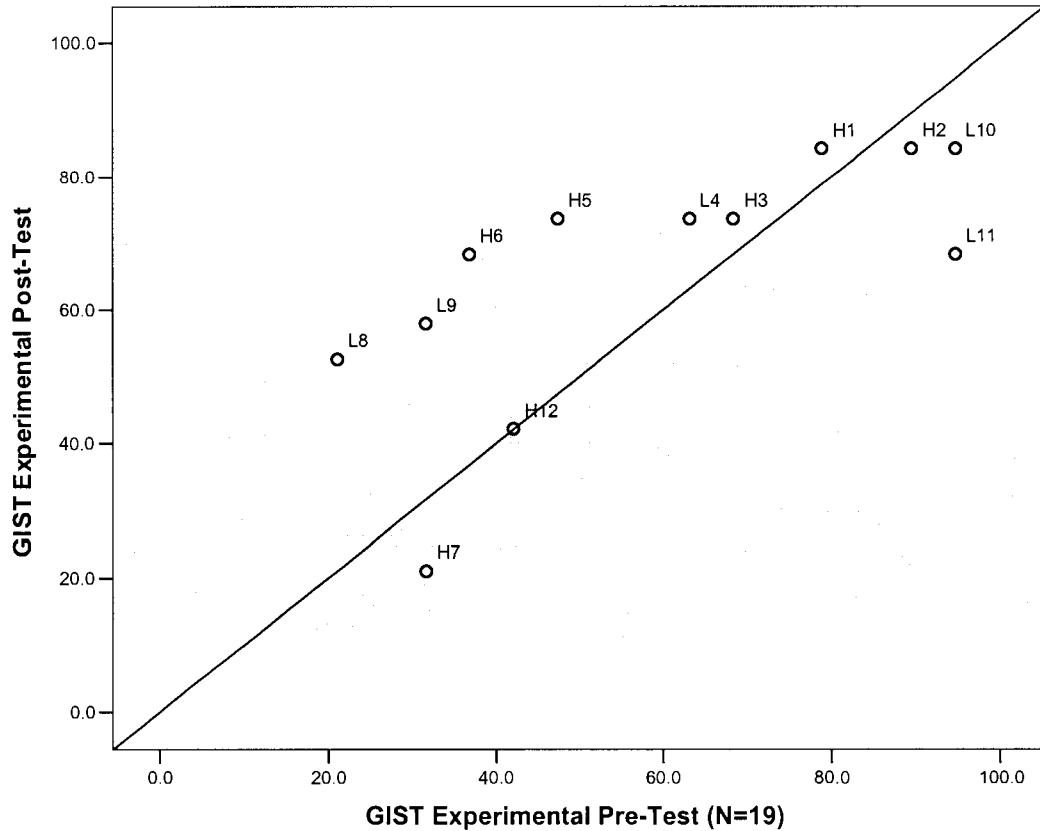


Figure 4.2: Item-level change from pre to post tests for GIST (pilot): Experimental Group. H = high inquiry, L = low inquiry. (Axes show percentages of students getting item correct.)

From data displayed in the scatter plots, the experimental students improved on more items and also on more items designated high inquiry on the GIST (1999) compared to the control group. The data tends to support the finding that the students in the experimental group with the use of CBL 2 technology and using inquiry based learning improved their graph interpretation skills.

#### *Instrument Item Analysis Based on Individual Scores*

To analyse these data further, there was a movement from comparing group scores between the two classes to looking at individual student improvement between the

control and experimental group. The researcher produced an Excel™ spreadsheet that indicated correct and incorrect responses from each student. By organizing the data in this manner, it was possible to determine the percentage of students that showed an increase, decrease, or no change from pre to post-test. Table 4.5 displays data for all 12 items for the GIST (1999). The percent of students who increased for both groups is very similar, within one percent of each other.

Table 4.5

Student responses from Pre-test to Post-test for GIST (all 12 items)

Scores	Control group (N = 26)		Experimental group (N = 19)	
	Number	Percentage	Number	Percentage
Increased	14	54	10	53
Decreased	9	35	8	42
No change	3	12	1	5

The percentage widened in favour of the experimental group when focusing on individual improvement for just high inquiry items (see Table 4.6). Nine of the 19 students in the experimental group increased compared to 11 of the 26 for the control group. Five percent more students in the experimental groups improved in their graph interpretation abilities than control. Findings from this data indicate that experimental and control classes improved in their ability to interpret graphs; however, the experimental group seemed to show greater improvement in areas of higher inquiry thinking skills.

Table 4.6

## Student responses from Pre-test to Post-test for GIST (high inquiry items)

Scores	Control group (N = 26)		Experimental group (N = 19)	
	Number	Percentage	Number	Percentage
Increased	11	42	9	47
Decreased	9	35	4	21
No change	6	23	6	32

*Journal Analysis*

Journal responses to questions for control and experimental groups provided the following results (see Table 4.7). From these data it was determined that 69% of the control group provided responses that were deemed satisfactory as compared to 82% for the experimental group. On average for the six journal days, the experimental group students chose questions categorized as low inquiry 59% of the time compared to 57% for the control. Experimental students chose medium inquiry responses 21% of the time while the control group chose them 30% of the time. Finally, the experimental group answered high inquiry responses 21% of the time, while the control group chose this category of questions 14% of time.

Table 4.7

## Percent Distribution for Journal Responses (pilot)

Rank	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6 & 7	
	C	E	C	E	C	E	C	E	C	E	C	E
1	4	0	4	0	25	18	36	5	74	73	4	0
2	13	55	70	63	29	36	8	5	26	14	48	82
3	4	5	4	0	0	0	0	0	0	0	4	0
4	39	36	22	0	25	45	44	15	0	14	35	9
5	17	0	0	0	8	0	0	10	0	0	0	0
6	22	5	0	37	13	0	12	65	0	0	9	9

Note: C = control group and E = experimental group.

### *Research Study Data Analysis*

#### *Descriptive Statistics*

The instruments for measuring changes in abilities to read and interpret graphs were the TOGS (1986) and GIST (1999) graph interpretation skills tests. Both control and experimental group averages increased from pre to post-test for TOGS (1986) and GIST (1999). The control group moved from 64% on the pre-test to 77% on the TOGS (1986) and from 48% to 55% on the GIST (1999).

Results for the control group for GIST (1999) are in Table 4.8. For both pre and post-test, the respective mean and median scores were very similar. The standard deviation was also very similar in pre and post-tests, suggesting that variation in student performance did not change for the control group. Descriptive statistics for the TOGS

control group results are in Table 4.9. Students' scores on the pre-test represent a wide range of abilities given that the standard deviation was very large. The median score was higher than the mean. This score indicates that although some students scored very high, producing a median of 11, some students scored very low, bringing down the mean. After the lessons, students not only improved as a group but students that had performed poorly prior to the lessons improved resulting in scores where all medians and means were similar. Standard deviations decreased from pre to post-test, suggesting that the group became more homogenous.

Table 4.8

Control Group Descriptive Statistics for GIST (maximum score = 12)

	Pre-test	Post-test
<i>M</i>	5.74	6.65
<i>Mdn</i>	6.0	7.0
<i>SD</i>	2.53	2.62
<i>N</i>	23.0	23.0

Table 4.9

Control Group Descriptive Statistics for TOGS (maximum score = 15)

	Pre-test	Post-test
<i>M</i>	9.61	11.57
<i>Mdn</i>	11.0	12.0
<i>SD</i>	3.87	2.52
<i>N</i>	23.0	23.0

From pre and post-test averages on the GIST (1999), the experimental group moved from 44% to 48%. For the TOGS (1986), the experimental group moved from 60% to 71%. See Table 4.10 and 4.11.

A similar situation occurred with the experimental group for the GIST (1999) as with the control group for this instrument (see Table 4.10). The standard deviations decreased from pre to post-test indicating that the lower end students improved more making the group more homogenous. Table 4.11 shows the TOGS (1986) descriptive statistics for the experimental group. Mean and median values for the pre-test were similar as were mean and median values for the post-test. Standard deviations decreased slightly.

Table 4.10

Experimental Group Descriptive Statistics for GIST (maximum score = 12)

	Pre-test	Post-test
<i>M</i>	5.31	5.77
<i>Mdn</i>	5.5	6.0
<i>SD</i>	2.53	1.97
<i>N</i>	26.0	26.0

Table 4.11

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 Experimental Group Descriptive Statistics for TOGS (maximum score = 15)
 

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	Pre-test	Post-test
<i>M</i>	8.96	10.62
<i>Mdn</i>	9.0	11.0
<i>SD</i>	2.78	2.71
<i>N</i>	26.0	26.0

---

In each case, except the GIST (1999) control group, the variances for the tests decreased from pre to post test. As a result of the lessons on heat energy that incorporated graph interpretation skills, the class became more homogenous in scores. The results of higher scores also suggest that each class acquired knowledge from the lessons taught during the study that allowed them to improve their skills in graph interpretation.

*t-test Analysis*

Comparisons between pre and post-test means for the GIST (1999) and TOGS (1986) utilized paired *t*-test methodology. For the control group there was not a significant improvement in GIST (1999) mean scores,  $t(22) = -1.61, p > 0.05$ . Also, there was no significant improvement from pre to post-test for the experimental group on the GIST (1999),  $t(25) = -.85, p > 0.05$ . Results from *t*-tests for GIST (1999), control and experimental groups, are in Table 4.12.

Table 4.12

Control and Experimental Group Paired *t*-test for GIST

Source	<i>N</i>	<i>M</i>	<i>SD</i>	<i>SE</i>	<i>T</i>	<i>Df</i>	<i>p</i>
Control	23	-.91	2.73	.57	-1.61	22	> 0.05
Experimental	26	-.46	2.77	.54	-.85	25	> 0.05

Interestingly, however, this was not the case for the TOGS (1986) test. Table 4.13 displays these results. Critical *t*-statistic values for the control and experimental indicate *p* values of less than 0.05; therefore, the mean scores between pre and post-tests were significantly different,  $t(22) = -2.66, p < 0.05$  for control and  $t(25) = -3.54, p < 0.05$  for the experimental. These results support the idea that abilities to interpret graphs did not just improve by chance, but were attributable to the instruction that took place.

Table 4.13

Control and Experimental Group Paired *t*-test for TOGS

Source	<i>N</i>	<i>M</i>	<i>SD</i>	<i>SE</i>	<i>T</i>	<i>Df</i>	<i>p</i>
Control	23	-1.96	3.52	.73	-2.66	22	< 0.05
Experimental	26	-1.65	2.38	.47	-3.54	25	< 0.05

Independent *t*-test comparing control and experimental means was necessary to determine the similarity between the two groups for both instruments (see Table 4.14). Data from descriptive statistics indicated that the control group had higher achievement to begin with given that their pre-test mean scores for GIST (1999) and TOGS (1986) were 5.74 and 9.61 respectively compared to experimental scores for GIST (1999) and

TOGS (1986), which were 5.31, and 8.96 respectively. Results from independent *t*-tests for GIST (1999) and TOGS (1986) are in Table 4.14. Both *t*-statistic critical values indicated that there was no significant difference between the groups,  $t(47) = .597, p > 0.05$  for GIST (1999) pre-tests and  $t(47) = .678, p > 0.05$  for TOGS (1986) pre-tests.

Table 4.14

Pre-test Independent *t*-test for GIST and TOGS

Source	<i>N</i>	<i>M</i>	<i>SD</i>	<i>SE</i>	<i>T</i>	<i>Df</i>	<i>p</i>
GIST					.597	47	> 0.05
TOGS					.678	47	> 0.05

An independent *t*-test comparing control and experimental post-test means for the GIST (1999) is in Table 4.15. The GIST (1999) mean scores for control and experimental groups were 6.65 and 5.77 respectively. It was determined that the control group did not improve significantly more than the experimental group,  $t(47) = 1.338, p > 0.05$ .

The independent *t*-test comparing post-test scores for control and experimental groups for TOGS (1986) gave results shown in Table 4.15. The mean scores suggested that the control group scored better than did the experimental group, 11.57 and 10.62, respectively. However, a *t*-statistic critical value indicated that there was no significant difference between the control and experimental groups on the post-test score means for the TOGS (1986),  $t(47) = 1.264, p > 0.05$ .

Table 4.15

Post-test Independent *t*-test for GIST and TOGS

Source	<i>N</i>	<i>M</i>	<i>SD</i>	<i>SE</i>	<i>T</i>	<i>Df</i>	<i>p</i>
GIST					1.338	47	> 0.05
TOGS					1.264	47	> 0.05

*Instrument Item Analysis Based on Group Averages.*

Another method of investigating changes in control and experimental group improvement was to determine the number of items showing improvement for all items and then just high inquiry items. To investigate group changes from pre to post-test with respect to individual test items, the researcher made a scatter plot, post-test vs. pre-test, for both the control and experimental groups. Also further classification of test items as high and low inquiry are on the scatter plot represented as H: high inquiry and L: low inquiry. The researcher classified the 12 items on the GIST (1999) and the 15 items on the TOGS (1986) as high inquiry and low inquiry. To document validity for the classification, four other teachers who had no stake in the study also classified the test items. Given that the teachers may not have been familiar with inquiry characteristics, they used a rubric for classifying questions as low and high. The comparison results are present in Table 3.3 on page 55.

Figures 4.3, 4.4, 4.5, and 4.6 show control and experimental group results for GIST (1999) and TOGS (1986) items. The data plotted show the item difficulties, and the proportion (percentage) of students getting those items correct.

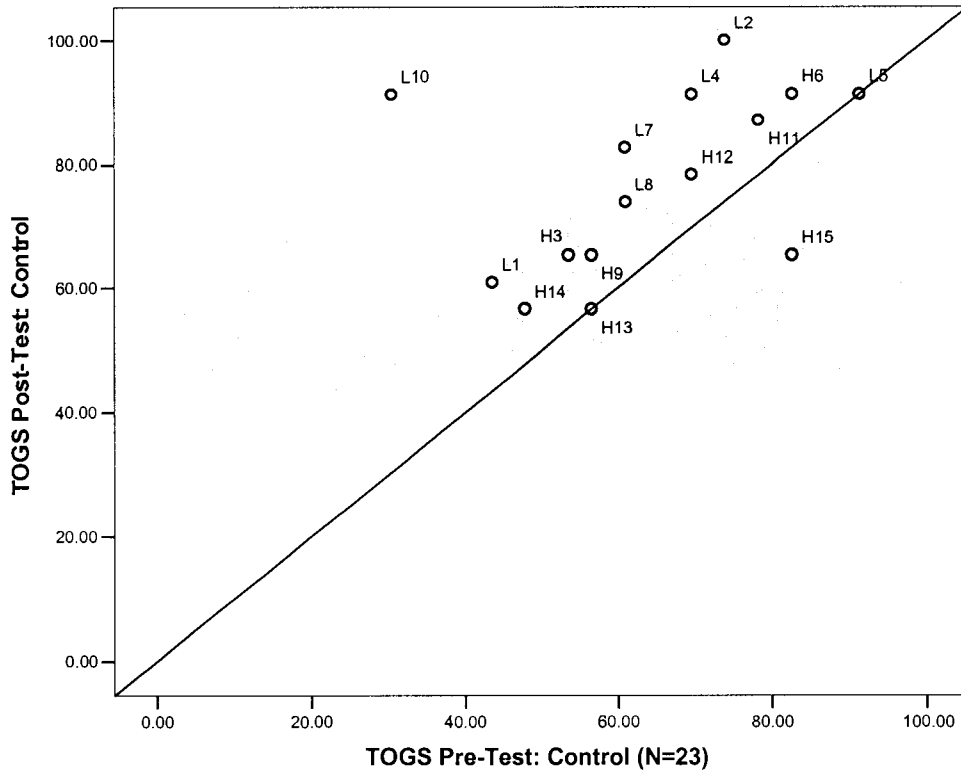


Figure 4.3: Item-level change from pre to post tests for TOGS: Control Group. H = high inquiry and L = low inquiry. (Axes show percentages of students getting item correct.)

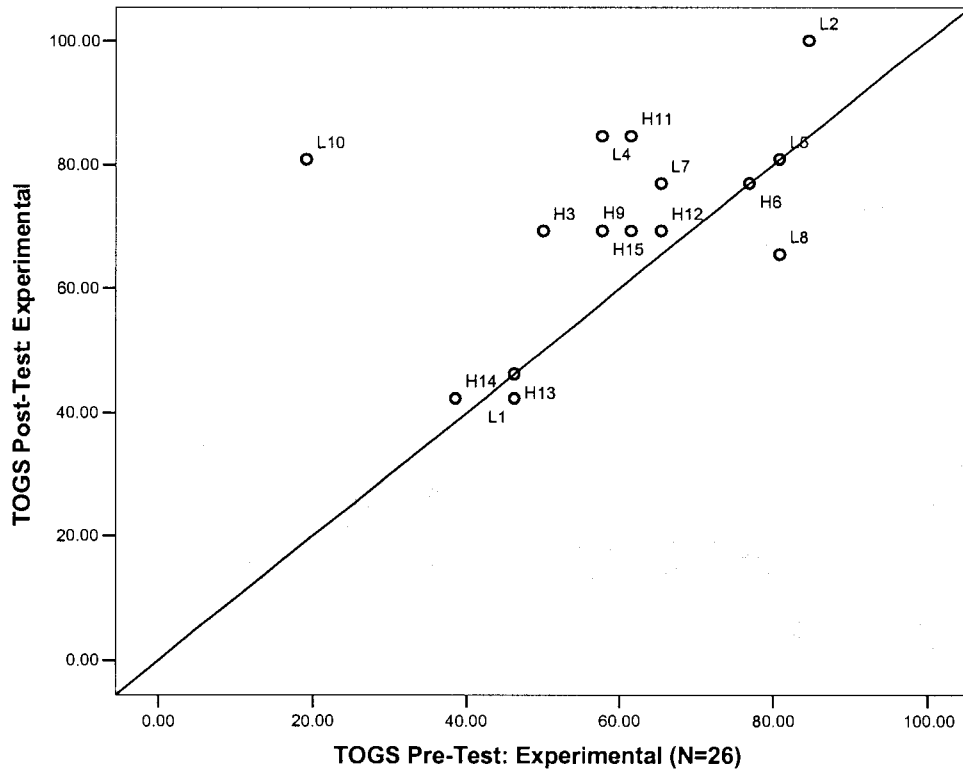


Figure 4.4: Item-level change from pre to post tests for TOGS: Experimental Group. H = high inquiry and L = low inquiry. (Axes show percentages of students getting item correct.)

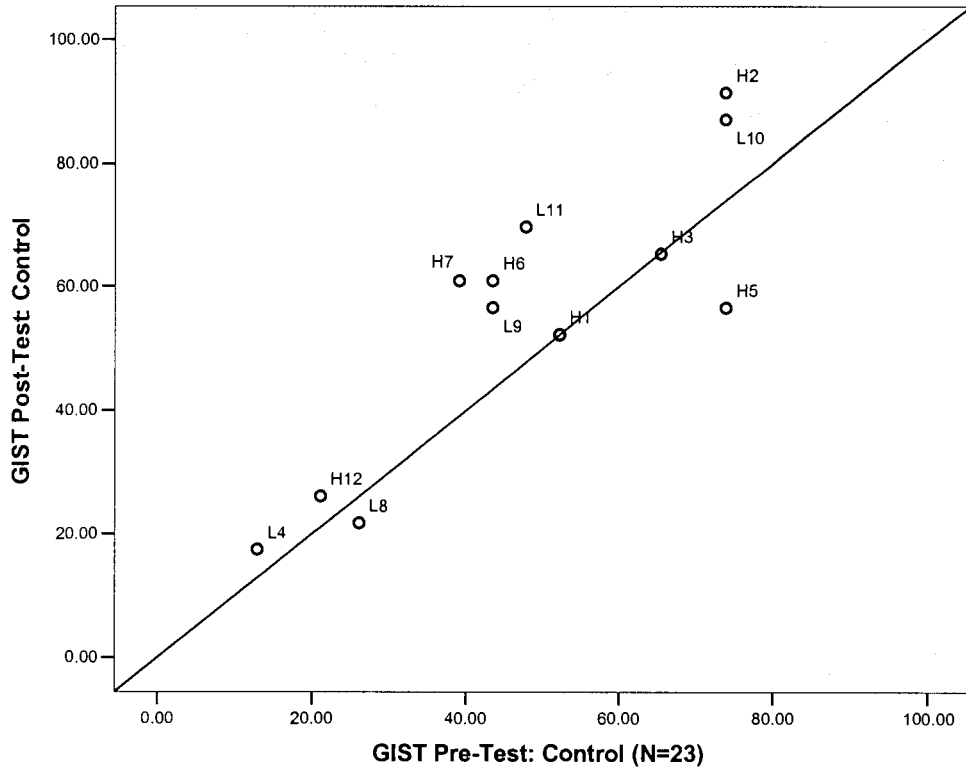


Figure 4.5: Item-level change from pre to post tests for GIST: Control Group. H = high inquiry and L = low inquiry. (Axes show percentages of students getting item correct.)

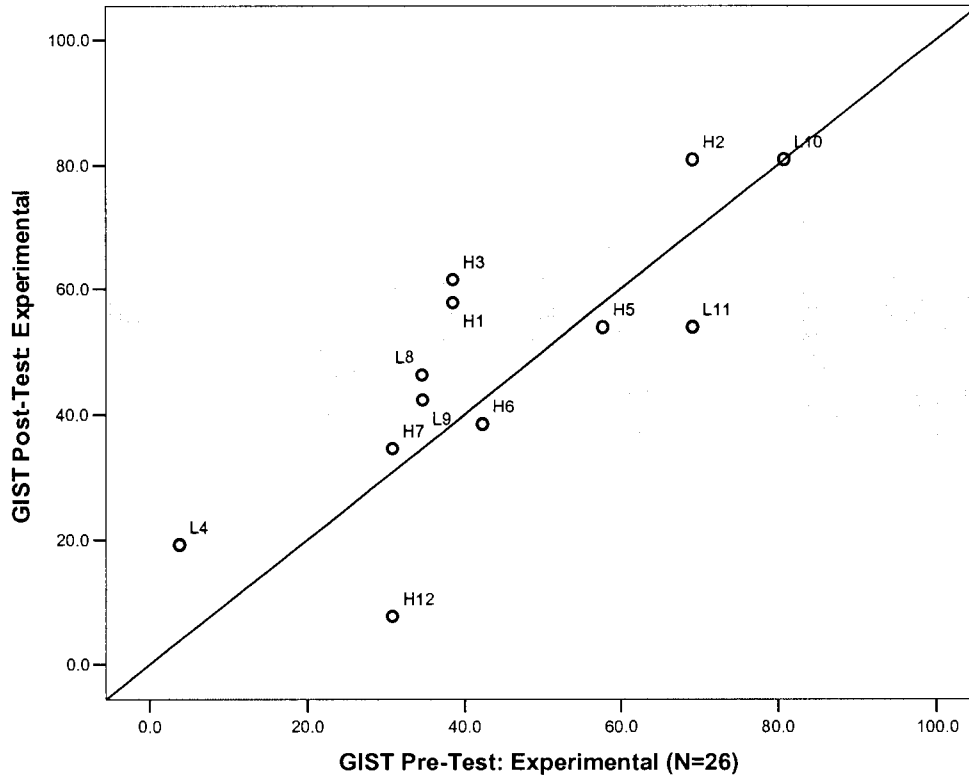


Figure 4.6: Item-level change from pre to post test on GIST: Experimental Group. H = high inquiry and L = low inquiry. (Axes show percentages of students getting item correct.)

When comparing the two groups, the control group improved on 80% of the 15 items on the TOGS (1986) test as compared to 68% improvement on the 15 items for the experimental class (Table 4.16). These findings were consistent with the results on the GIST (1999). The control group as a whole improved more than the experimental group (Table 4.17). These findings suggest that, based on class averages, the control as a group acquired a greater understanding in graph interpretation.

Table 4.16

## Group responses from Pre-test to Post-test for TOGS (all items)

Scores	Control group		Experimental group	
	Number	Percentage	Number	Percentage
Increased	12	80.0	10	67.7
Decreased	1	6.7	2	13.3
No change	2	13.3	3	20.0

Table 4.17

## Group responses from Pre-test to Post-test for GIST (all items)

Scores	Control group		Experimental group	
	Number	Percentage	Number	Percentage
Increased	8	67.7	7	58.3
Decreased	2	16.7	4	33.3
No change	2	16.7	1	8.3

One of the study's main themes was to look at the effect of CBL 2 technology on students' ability to improve with respect to answering inquiry-based questions. It was therefore necessary to compare improvements on high inquiry items. Tables 4.18 and 4.19 show the percent improvement for each group on both GIST (1999) and TOGS (1986) tests.

It was determined that both groups showed the same improvement on high inquiry items, 75%, for the TOGS (1986). However, unlike the control group, the experimental class did not decrease in score from pre to post-test on any high inquiry item. A very similar result occurred on the GIST (1999) where again both groups improved the same percent on high inquiry questions, 57%.

Table 4.18

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 Group responses from Pre-test to Post-test for TOGS (high inquiry item)
 

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Scores	Control group		Experimental group	
	Number	Percentage	Number	Percentage
Increased	6	75.0	6	75.0
Decreased	1	12.5	0	0.0
No change	1	12.5	2	25.0

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Table 4.19

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 Group responses from Pre-test to Post-test for GIST (high inquiry items)
 

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Scores	Control group		Experimental group	
	Number	Percentage	Number	Percentage
Increased	4	57.1	4	57.1
Decreased	2	28.6	3	42.9
No change	1	14.3	0	0.0

---

Some test items on the TOGS (1986) showed great improvement. See, for example, Figure 4.3 and Figure 4.4 item L10. Starting at 30% correct for the control pre-test, the post-test results showed more than a 60% improvement ending up with 91% of the class answering the question correctly. A similar 60% improvement was in the experimental class where the pre-test result was 19.2% and ended at 80.8% on the post-test. Question 10 on the TOGS (1986) was a construction-based question that asked students to determine which of four lines drawn for a scatter plot was the best fit (see Appendix D). Given that very few students would have been familiar with the term 'line of best fit' prior to the study it was not surprising for there to be a large improvement from pre to post-test. Another outlier data point occurred on Figure 4.6 GIST (1999) experimental group. Item H12 showed a large drop in percentage from pre (30.8%) to post-test (7.7%). Item 12 on the GIST (1999) was a difficult question for control and experimental students for the control pre-test score was 21.7% and post-test 26.1%; neither group scored well on that item. This still did not explain why the post-test score for the experimental was so much lower. A possible answer, determined by an item analysis showed that four students in the experimental group omitted this item on the posttest. If these students had all scored a correct response, the post-test experimental percentage would have been a maximum of 23.1%, not that different from the control post-test score of 26.1% correct.

#### *Instrument Item Analysis Based on Individual Scores.*

After looking at trends suggested by group averages, the research examined individual improvements. Table 4.20 and 4.21 display the findings for improvement at the individual student level. A different story developed for individual improvements. For

the GIST (1999), 50.0% of students in the experimental class improved as compared to 47.8%, of students in the control class. Duplication of these findings resulted on the TOGS (1986) as well. Here 65.4% of the students in the experimental class improved compared to 60.9% in the control. It appeared that the experimental group had greater improvement. Another note worthy finding in these tables was that in both the TOGS (1986) and the GIST (1999) the percent showing a decrease from pre to post-test is smaller in the experimental group. This may be interpreted that, teaching using traditional methods may not facilitate students' ability to learn necessary skills for interpreting graphs.

Table 4.20

Student responses from Pre-test to Post-test for GIST (all items)

Scores	Control group (N = 23)		Experimental group (N = 26)	
	Number	Percentage	Number	Percentage
Increased	11	47.8	13	50.0
Decreased	9	39.1	9	34.6
No change	3	13.0	4	15.4

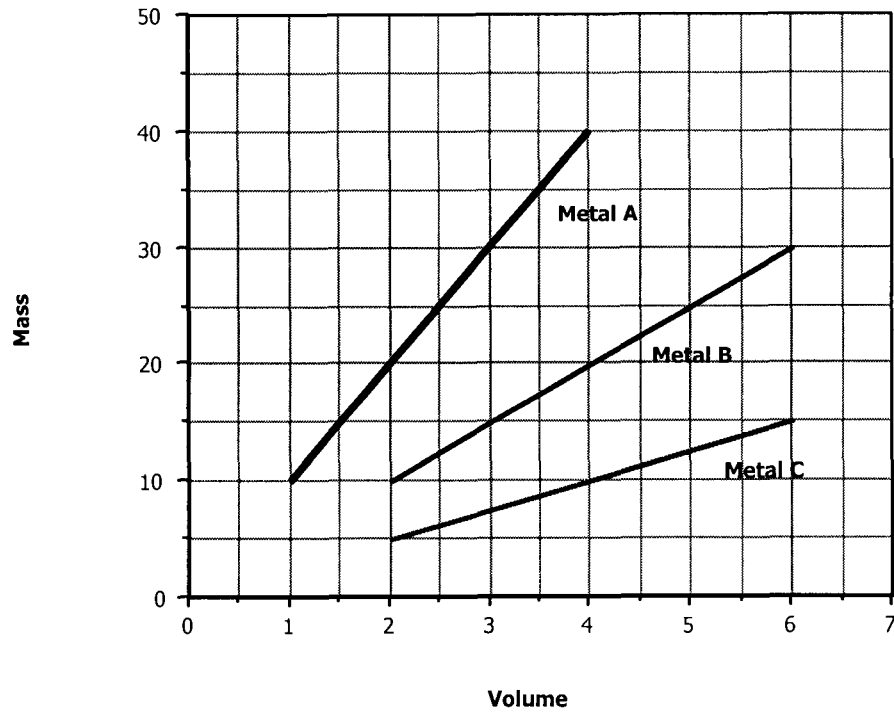
Table 4.21

## Student responses from Pre-test to Post-test for TOGS (all items)

Scores	Control group (N = 23)		Experimental group (N = 26)	
	Number	Percentage	Number	Percentage
Increased	14	60.9	17	65.4
Decreased	5	21.7	5	19.2
No change	4	17.4	4	15.4

In support of Research Question One, it was of interest to the researcher to investigate not just improvement on the whole test but to look at how students did on the high inquiry items. An example of low and high inquiry test question from the GIST (1999) can be viewed in figure 4.7.

•The density of a metal is the ratio of mass divided by volume. An experiment was set up to measure the density of three metals. For several different masses of the same metal, the volume it occupied was measured. These were plotted on the graph below.



Low inquiry:

What is the slope for the line for Metal A?

- 0.10
- 3.0
- 10.0
- 30.0

High inquiry:

Which metal has the smallest density?

- metal A
- metal B
- metal C
- all the same

Figure 4.7: Sample question of low and high inquiry question from GIST graph

interpretation skills test.

Comparing the students on their individual improvement but narrowing the sample of questions to just those that are high inquiry created the following results. In Table 4.22 and 4.23 results showed that for both GIST (1999) and TOGS (1986) the differences between control and experimental groups were even more noteworthy. Here GIST (1999) results showed that 53.8% of the students in the experimental group compared to 47.8% in the control group improved. This difference was even more evident in the TOGS (1986) test when high inquiry items were isolated. The experimental group resulted in a 57.7% improvement compared to a 39.1% improvement in the control. Again, the same trend occurred in students scoring a decrease from pre to post-test. More students in the control class scored a decrease on their post-test than did the experimental students. This was a consistent result in all findings.

Table 4.22

Student responses from Pre-test to Post-test for GIST (high inquiry items)

Scores	Control group ( <i>N</i> = 23)		Experimental group ( <i>N</i> = 26)	
	Number	Percentage	Number	Percentage
Increased	11	47.8	14	53.8
Decreased	8	34.8	8	30.8
No change	4	17.4	4	15.4

Table 4.23

## Student responses from Pre-test to Post-test for TOGS (high inquiry items)

Scores	Control group ( <i>N</i> = 23)		Experimental group ( <i>N</i> = 26)	
	Number	Percentage	Number	Percentage
Increased	9	39.1	15	57.7
Decreased	7	30.4	6	23.1
No change	7	30.4	5	19.2

These latter results conclude the analysis of the quantitative data created from the pre- post-test using the two graph interpretation skill tests, GIST (1999) and TOGS (1986).

*Journal Analysis*

Journal responses to questions for control and experimental groups provided the following results in Table 4.24. From these data, the researcher determined that 92% of the control group provided responses that were satisfactory as compared to 78% for the experimental group. On average for the six journal days, the experimental group students chose questions categorized as low inquiry 57% of the time compared to 49% for the control. Experimental students chose medium inquiry responses 26% of the time as did control students. Finally, the experimental group answered high inquiry responses only 16% of the time, while the control group chose this category of question 25% of time. The following represents one day's journal questions for student response.

## Day 3: Conduction

1. Gold is a better conductor than copper. Use a graph to show what the slope of gold would look like compared to copper. (High inquiry)
2. Define 'conduction' in your own words. Use full sentences. (Low inquiry)
3. Give an example of where conduction could be applied in your daily life.  
(Medium inquiry)

Table 4.24

Percent distribution for Journal Responses (study)

Rank	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6 & 7	
	C	E	C	E	C	E	C	E	C	E	C	E
1	0.0	0.0	0.0	15.8	0.0	20.8	0.0	0.0	0.0	4.8	18.2	20.0
2	0.0	20.0	85.7	63.2	14.3	33.3	4.8	0.0	100.0	90.5	72.7	76.0
3	10.5	0.0	0.0	0.0	4.8	8.3	0.0	4.8	0.0	4.8	0.0	0.0
4	31.6	50.0	0.0	0.0	81.0	37.5	28.6	47.6	0.0	0.0	0.0	4.0
5	10.5	15.0	0.0	21.1	0.0	0.0	0.0	14.3	0.0	0.0	9.1	0.0
6	47.4	15.0	14.3	0.0	0.0	0.0	66.7	33.3	0.0	0.0	0.0	0.0

Note: C = control group and E = experimental group.

The results from scoring journal entries indicated that those students in the control class chose higher level thinking questions more often than the experimental students.

Not only did control students choose to answer higher-level questions, these students answered the particular questions to a satisfactory level more often than the experimental class. The researcher noticed that the traditional class had more time at the end of class to

write their journals than the experimental. The traditional class was teacher controlled; therefore, transitions from one topic to another were easier to manage time wise. Since the experimental class was student based, a lot more topical discussion and group procedure planning took place. As a result, the guided inquiry approach often took more time and there was less class time for journal writing. There was also more time in control classes for these students did not have to set up equipment or collect their own data like those in the experimental class. The results in Table 4.24 may not be from lack of higher level thinking on the part of the experimental students but from learning from a guided inquiry perspective in a fixed amount of time.

An example of a correctly answered high-level question is “If you shook the container fast the slope of the graph would go higher because of friction.” An example of an incorrectly answered high-level question is “If I shook a container faster, it would move the slope would change because of friction (*sic*).” Although there is an indication that there is a relationship between change of slope and friction, this latter student was not able to connect the idea that the increase in slope was a direct result of the increase in friction (heat), unlike the first student. Day 5, heat radiation, is the only day where experimental students chose higher-level questions more often than control students, although their responses were marked unsatisfactory.

### *Interview Analysis*

The researcher conducted interviews of a semi-structured format with four control and four experimental students. Each group of four consisted of two high cognitive and two low cognitive students as designated by their regular teacher. For analysis, the researcher used only two student responses, one high rank and one low, from each of the

two groups. Those students chosen represented the clearest responses to questions for the particular question.

The first question and answers for analysis was, *what part or parts of the lessons did you enjoy? Why?*

Control Low Student (CLS): *When we went in our groups and did the things with the thermometers.*

Interviewer (I): You did what things with the thermometers?

CLS: *When we put it in our things that hold heat.*

I: Oh the insulators. Why did you enjoy that?

CLS: *Because I had fun making it with the groups.*

Control High Student (CHS): *I liked the demos and sciency stuff.*

Experimental High Student (EHS): *I liked doing the experiments because they were fun.*

I: What was fun about them?

EHS: *Just learning the different things and using the equipment?*

Experimental Low Student (ELS): *How we got to get up and move around. Stuff like that. Hands-on activities.*

I: You like doing those activities?

ELS: *Yeah.*

I: What were some of those activities?

ELS: *Using the calculators and getting the temperature of the metal bars and stuff like that.*

In all interviews, students in both groups indicated that they enjoyed activities that had them moving around, working in groups, and doing experiments. Two of the eight students used the term “hands-on” to describe the various activities, one of which is reported above. All four of the students in the experimental group responded favourably when discussing CBL equipment. Terms such as “calculators”, “equipment”, and “heat probes” were used by the students. From the responses, students in the experimental group exhibited positive attitudes towards the use of the CBL equipment. Students had positive affective behaviours towards activities; therefore, by transitivity, these results

indicate that hand-held technology can promote teaching students from a guided inquiry hands on perspective.

Question two from the interviews asked: *Who asked the questions, the students or the teacher? Who is providing the answers to the questions, the students or the teacher?*

CHS: *I think it was you.*

I: Do you feel you discovered your own answers or even think of the convection poster did you figure out how air currents were flowing or did I tell you?

CHS: *I think we found out for ourselves.*

I: How did you find out for yourself? Where did you get that information from?

CHS: *The movie.*

CLS: *I think you would ask most of the questions and answer some of the questions.*

I: That kind of goes to my next question. Who would be providing the answers to those questions?

CHS: *You.*

ELS: *You provided the questions but we had to answer the questions with your guide lines but you helped us along with the answers so that we could understand them.*

I: So I laid out the questions but you provided the answers. How did you go about trying to solve this question?

ELS: *It would depend on the question.*

I: Think about the CEO problem the one with (the) pan handle. Remember?

ELS: *The conduction problem?*

I: Yes, the conduction problem?

ELS: *... we figured out how aluminum and copper heat temperatures rose and we figured out that copper conducted heat better than aluminum because the heat rose faster in the same amount of time.*

EHS: *I was figuring out stuff too. And I would get help.*

I: Like what kind of things were you figuring out?

EHS: *All the work stuff and then I got help on the calculators and stuff like that.*

I: So more on like how to figure out the calculator. Who do you think was asking the questions? Was it the teacher asking questions or were the students coming up with their own questions?

EHS: *What do you mean?*

I: Like when we were trying to solve one of the problems.

EHS: *The teacher.*

I: So who do you think was providing the answers? Was it you figuring out the answers or was the teacher giving you the answer?

EHS: *Kind of both. We would do it and then you would give us the answer so we could check ours over.*

General conclusions drawn from this data were that students in the traditional classes did not ask any of the questions but more importantly, they did not determine answers to questions. Students in this class were dependent on the teacher providing the answers. In some situations, the teacher did not directly state the answer but provided a means for students to copy the answers such as providing a video that directly stated a possible answer. It was not typical to challenge the students in this class in order to have them find the answers.

Students in the experimental class responded that they were the ones that answered the questions asked by the teacher. In their responses, they also reported that the technology helped them draw their conclusions. The lessons were characteristic of guided inquiry for the teacher was asking the questions. Due to time constraints, the researcher did not utilize open-ended inquiry techniques in this study; therefore, having the teacher provide the questions was reasonable. Technology such as CBL 2 equipment was important for facilitating learning from an inquiry perspective for the equipment aided the students in their discovery of the answers to the problems.

The third question asked the students to provide a procedure for solving a given real world problem and create data that they might expect to collect and how they might display that data. The question was termed the “Coffee cup cooling question”. The question asked was as follows.

*I need your help to solve a problem. I have mixed up two coffee cups one has a lot of sugar in it and the other has no sugar. They are for some company so I do not want to*

*taste them to tell which is which. However, I have heard that liquids cool slower when they have things like sugar dissolved in them. From this information, please tell me a method to solve this problem and what sort of data could I collect and display to answer this question?*

Follow up question:

*I have two graphs of data that were collected, which one belongs to the cup with sugar in it (or with no sugar in it)?*

The two graphs to choose from were similar to the following two graphs with increasing temperature on the y-axis and increasing time on the x-axis (Figure 4.8).

Graph A displays data that could represent cooling coffee with sugar. Since the students worked with linear data during the study an exponential curve, was not drawn even though it represents the ideal curve for the cooling of a liquid.

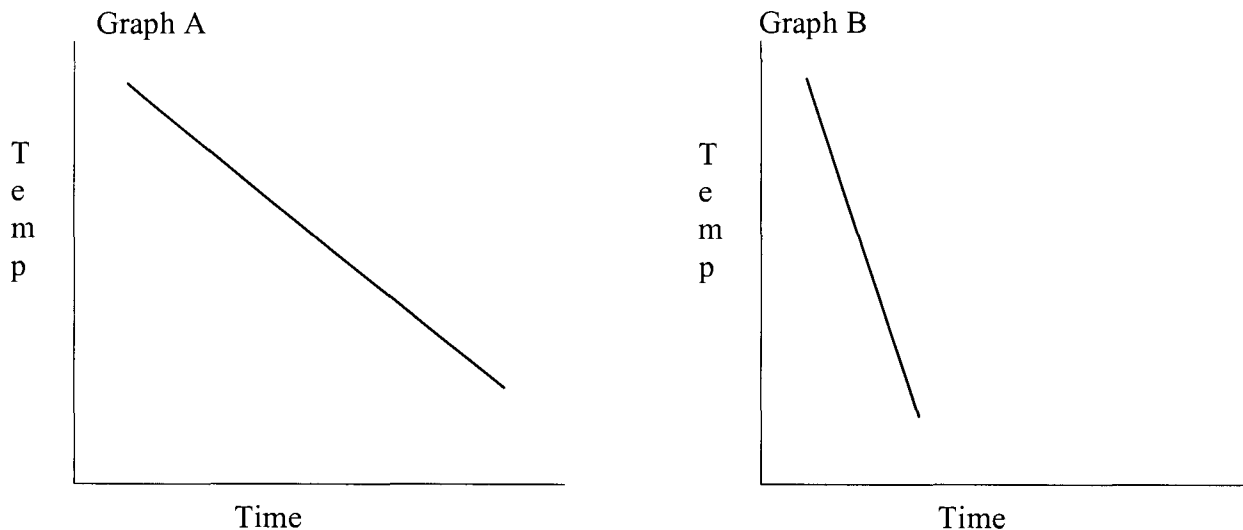


Figure 4.8: Graphs used to support interview questions.

CLS: *You could probably get a thermometer and put it in each cup.*

I: *What else would I have to do? So I'd have the thermometer in and I'd do what with that thermometer just stick it in and pull it out.*

CLS: *Check the temperature and see which one is cooling faster.*

I: *What kind data would I need to collect? .... What kind of data would you write down to solve this problem? ..... You might have mentioned a*

few things. .... What would my data look like do you think you could even draw a picture of what this data might look like. Do you have an idea? ....

CLS: *Yeah.*

I: Would you like to try and draw a picture of that? (Student draws) What would your data look like for the coffee cup with sugar in it? (Student keeps drawing) What do the results look like? .... So you are saying you would have a lower temperature in the sugar one and more heat in the other one. Great.

I: If I gave you these two graphs. (I showed him the two graphs) which one do you think would describe the one with sugar in it?

CLS: (Student chooses B).

CHS: *Like you could use the thermometer and measure the temperature of each cup and which one is higher would have the sugar and the one that is lower would not have the sugar.*

I: What would some of your data look like? Could you draw me a picture of what your final data might look like? (student draws her data)

CHS: *Like the one without sugar would be 20 and the one with would be 25 it is going down slower.*

I: If you had displayed your data as a graph which data graph would you say represents the one without sugar?

CHS: *What does this mean?*

I: Temperature vs. time.

CHS: *This one.*

I: You are pointing to A would be without sugar.

ELS: *Take a heat probe and put it in one of them or if you have two you could put it in both of them at the same time. And wait a couple of seconds and check the temperatures and which ever was hotter for a longer period of time would be the one with sugar in it.*

I: The one with the sugar in it. So what kind of data would you collect?

ELS: *On the coffee?*

I: Yes.

ELS: *That sugar with just a little coffee in it holds in heat better.*

I: Okay but what kind of numbers data would you want?

ELS: *You would want it to be higher hotter because which ever one is higher is the one with sugar in it?*

I: Yes sure. Could you draw for me what you think your data might look like?

ELS: *How hot do you want it to be?*

I: 80 degrees.

ELS: (Student draws graphs).

I: What would be the data so that you could hand to me and say hey Mr. Travers this is what I collected and this is why I think that this cup has sugar in it and this one does not have sugar in it.

ELS: (Student keeps drawing).

I: So this is with sugar and without sugar. I am going to show you one picture. Which graph do you think represents with sugar and which graph do you think without sugar?

ELS: *Graph A has sugar.*

EHS: *You could take the temperature and the one that is higher is the one with sugar.*

I: Okay. How would you go about collecting this data?

EHS: *I do not know-get a thermometer?*

I: Are there other things you might do?

EHS: *I am not sure?*

I: What do you think the data might look like? .... What kind of data might you collect? .... How could you display it? What would the data look like after you collected that information?

EHS: *Would a cup of coffee with sugar in it be more hotter than the other one?*

I: Could you write or just kind of show me what kind of data you would collect and or what that data would look like? .... How could you display that data for me?

EHS: (She draws).

I: Okay so you would take the temperature and by looking at it be able to tell which one is which. That is great please put your name on it.

I: If I had given you these two graphs which one do you think would represent the one that had no sugar in it?

EHS: *That one.*

I: How come?

EHS: *I do not know what word to use.*

I: What word are you looking for?

EHS: *It is not as steep as the other one.*

I: This is not as steep as this?

EHS: *Oh yeah right. That one.*

I: Which one has the sugar in it (she picks B).

The results from the interviews indicate that students in the control group had difficulty conceptualizing data in order to answer the real world problem. All control students mentioned methods that involved taking temperatures and only one mentioned a procedure of taking the temperature over a period. This student mentioned the possibility of displaying the data as a graph but drew a table instead. Only one student in the control group chose a graph to display their findings; however, labeled the axis incorrectly, drew

positive slopes and mislabeled the slopes by indicating incorrectly, which graph would have sugar. Two control students represented their data by displaying a table, one included data that was correct and one did not include any data just headings. The fourth student drew a picture of coffee cups having thermometers sticking out of them labeling the one cup with sugar “lower temp” and the no sugar cup with labeled “more heat”. When presented with a possible graph that may have been created from data collected to solve the problem none of the control students, high or low level, correctly selected graph A, or in one case Graph B when asked which graph represented cooling coffee with no sugar added?

Three out of four experimental students mentioned using heat probes, CBL 2 technology, in their procedures. Two out of the four correctly drew and labeled graphs that might represent data collected from their experiment and three out of four experimental students were correct in determining that Graph A was the correct graph to represent coffee with sugar in it. The two lower level students drew pictures of the procedure to represent the data; however, the student correctly labeled the coffee cup with sugar in it as having a higher temperature. The fourth student drew two thermometers to represent data and labeled correctly the thermometer in the sugar cup as having a higher temperature than the thermometer in the no sugar coffee cup. Students in the experimental class when interviewed and asked to solve a problem provided more evidence that supported that they had a better understanding of how to problem solve and were more aware of how data can be represented in order to draw conclusions that could be used to answer the question. Students mentioned CBL 2 technology in their

procedures and stated procedures that indicated that students were learning science from an inquiry perspective.

### *Summary*

Finding from quantitative and qualitative data aided answering the two research questions. Data provided from the TOGS (1986) and GIST (1999) indicated that for at least one of the tests there was a statistically significant improvement on test scores for the experimental group. It was also determined that the control class benefited even though they worked in a traditional setting. The most important finding from the data was in the number of students that improved on each test. Furthermore, results found that more experimental students improved on the TOGS (1999) and GIST (1986). These data supported the research question referring to CBL 2's ability to help improve graph interpretation skills. It was determined that qualitative data provided a rich resource for helping interpret the quantitative data.

Journal finding showed no clear results in support of CBL 2's ability to facilitate learning science from a guided inquiry hands-on perspective. However, interviews provided ample support in order to answer the research questions. Students in the experimental group displayed support for using CBL 2 technology. This group was better at describing methods for solving problems and interpreting graphs in an interview setting. Finally, students in the experimental group that learned science from a guided inquiry, hands-on perspective felt that they had provided their own learning, a characteristic of guided inquiry.

## Chapter 5: Discussion

This section summarizes and discusses findings that lead to answering the two research questions for this project. For each research question, there is reintroduction of qualitative and quantitative data collected during the research study, summarization of findings, and then discussion. In the discussion, some results from the pilot study are included, since they help to shed light on some of the findings from the main study. Finally, there is presentation of limitations of the research study along with future research considerations that follow from this study.

*RQ1: Does hand-held technology, CBL 2, help promote guided inquiry, hands-on based teaching methods? If so, to what degree?*

To determine if inquiry learning occurred in the experimental group, students responded to a varied level of questions using a journal format. From the journal data with the grade eight classes it was hard to conclude that students using technology were more inclined to try to answer questions of a higher cognitive inquiry level than those in the control group. This lack of findings may reflect the grade level of the students. Writing in science using a journal approach is unfamiliar and unappreciated by many grade 8 students. Because students find writing distasteful, some teachers have found little noteworthy results and have turned away from pencil and paper journals (Piburn & Middleton, 1997). Furthermore, the students at this level may not have been comfortable with group work. A possible explanation for this observation was that due to their lower maturity level, some individuals might have chosen to answer the question that just seemed easiest in order to *save face*.

In contrast, the pilot study with Grade 11 chemistry students provided a different picture. They were, of course, more mature, and were more comfortable with working in small groups. Just focusing on higher cognitive level questions, the experimental group increased percentage wise, more than the control, as the study progressed. Given that the control group performed better at the start this may have been indicative of the fact that students in the experimental class had to first adjust to using the new equipment but once they became more familiar, they were able to think at a higher level. The inquiry approach used with experimental students was set up to challenge students to begin to think and solve problems on their own (Polman & Pea, 2001). Although inquiry learning is more difficult (Edelson, Gordin, & Pea, 1999) for students, results from journal entries tend to demonstrate that some pilot experimental students were motivated to attempt answering more challenging questions.

Interviews for the main study presented evidence that students in the experimental group felt that they were the ones finding answers to questions presented by the teacher. This is in contrast to those in the control group who stated that the teacher gave the answers. Since learning from a guided inquiry perspective was the approach, it was acceptable for students to indicate that the teacher was asking questions for that day's investigation. In learning from an inquiry perspective as opposed to a teacher directed traditional approach, it was found that students are more likely to do their own learning. The students seemed to move from being passive to active about their own learning as the result of the integration of CBL 2 technology into the inquiry teaching strategy. Real-time graphing of data appears to be important for cognition and motivation (Brasell, 1987). In this research, it was not just the technology providing the inquiry, it

was the approach provided by the teacher. Technology is a tool that can facilitate inquiry learning; however, unless teachers have well integrated the technologies in the teaching of science concepts students will not benefit from using these tools (Krajcik & Layman, 1992).

Students in the experimental group provided more detailed and appropriate procedures for problem solving. For example, one student responded during an interview, *Take a heat probe and put it in one of them or if you have two you could put it in both of them at the same time. And wait couple of seconds and check the temperatures and which ever was hotter for a longer period of time would be the one with sugar in it.* The teaching methodology of inquiry-based learning challenges students in the classroom to think of methods to solve real world problems and test their procedures using CBL 2 technology. Other studies have produced similar results (Wetzel, 1999).

Interview data in contrast to journals were rich in providing information for answering Research Question One. In this study, there was evidence of student learning using an inquiry perspective promoted by the use of hand-held technology, CBL 2. In conclusion, the attempts to teach using a guided inquiry hands-on approach were successful when facilitated by technology and student learning improved.

*RQ2: Does the use of hand-held technology, CBL 2, help improve student graph interpretation skills?*

Interview data provided evidence in support of Research Question Two. Three of the four experimental students compared to none of the control students correctly identified the graph corresponding to a provided problem scenario. This result may have occurred because the experimental students had more experience in problem solving and

how to create data due to their hands-on work with CBL 2 technology. The control students encountered data as just being numbers, with little significance to what those numbers might represent given that they had little opportunity to personalize the data by creating it themselves.

Study results from the pre and post-tests for TOGS (1986) indicated that there was significant improvement in experimental and control students' cognitive ability to read and interpret graphs. In order to create a teaching unit in science that used CBL 2 technology it was necessary to provide numerous experiences that involved graphing. In order to provide lessons for the control and experimental that differed only in their teaching strategy and CBL 2 technology, there were many opportunities in which the control were learning and using graph interpretation skills. As a result, it was not surprising to see improvement in both groups.

For the GIST (1999) it was determined that the experimental groups did not improve and any increases in means may have just been the result of chance. This was also the case with the pilot data. Neither the experimental nor control group showed a significant improvement from pre to post-test at a  $p$  value of 0.05.

For all pre and post-tests, students completed the TOGS (1986) before the GIST (1999). Completion of both tests occurred in the same setting and sitting. Students may have done poorly on the GIST (1999) because of being tired of test writing and rushing through the last test. The students were aware that neither the TOGS (1986) nor the GIST (1999) scores influenced their grades. Therefore, students might not have taken the tests seriously. In the interviews, one student who was asked why he got one of the last questions wrong on the GIST test responded, *we had other assignments to work on so I*

*had to rush through it.* It may have been sufficient to use either the TOGS (1986) or GIST (1999), as the instrument for measuring graph interpretation skills. In this way, the researcher may have avoided students doing poorly because test length was too long. Administration of tests on two separate days may have removed the length of the tests as a factor. Findings in the literature also indicate that although students may be learning science using inquiry methods they may resort back to previous methods and preconceptions for solving problems during tests, especially when time is a limiting factor (Svec, 1999).

It was determined from an independent *t*-test that neither group improved a significant amount over the other in their post-tests. However, the mean score for the control was higher than the experimental. This may have occurred primarily because the control group had started out with a higher mean score. Although not significant the difference deserves some explanation. One possible reason for this may have been that on the post-tests for the experimental group four of the 26 students failed to answer a maximum of two questions. The researcher determined this by looking at the student scorecards during the analysis; however, it was too late to have those students give a response. These students may have felt rushed through the test, bored, or just over looked the questions. Given that no response was provided, the opportunity to get the correct answer even by chance was eliminated and therefore the average for the class may have been lower than it actually was. There were no questions not responded to from the control group.

Data from the item-level analysis demonstrated several interesting conclusions. The researcher compared percentage improvement from pre to post-tests from each

group, item for item. Both the TOGS (1986) and GIST (1999) revealed that as a group the control students improved on more items than the experimental.

A reversal in improvement occurred, when examining individual student improvement instead of looking at how the group improved. Students that worked with hand-held technology were outperforming students taught in a traditional non-technological setting. The percentage favouring the experimental group was minimal, less than 5%. However, when examining improvement on test items for high inquiry items improvements were greater than 17%. A similar improvement occurred on high inquiry items during the pilot study.

A possible explanation for this event was the following. Students in the control group learned graphing skills by having data supplied, scales for X and Y-axes set up in a group setting, and teacher indicating the scale. However, the students plotted graphs and answered questions that involved interpretation of the graphs. In the experimental class, students using CBL 2 technology collected data necessary to answer that day's questions. Although there was no first hand construction of the graphs, the students had to figure out scales independent of the teacher. This added skill may have contributed to interpreting graphs better; therefore, assisting students to score higher than those in the control class. An inquiry-based method of instruction facilitated by hands-on data collection using CBL 2 technology versus traditional methods of instruction may have made the difference. The stated results were in support of Research Question Two, Does hand-held technology, CBL2, help improve graph interpretation skills.

As a final note, statistical analysis of quantitative data from both TOGS (1986) and GIST (1999) indicated that control and experimental groups were statistically similar.

The fact that the control group scored higher may be because the control group as a whole was a unique group of students. These students all take part in a soccer academy where parental support is very high, the students want to attend school, and accordingly have a better attitude towards school and schoolwork than those in the experimental group. Their class term averages reflect this attitude and were higher than that of the experimental class. Marks accumulated over a semester resulted in averages of 73.5% with a standard deviation of 14.1 for the control group compared to 67.7%, standard deviation 12.5, for the experimental group.

It was reasoned that having this unique group as the control was beneficial. It is important to note that the researcher chose the experimental group randomly. If this unique group had been the experimental rather than the control group, one might have argued that any results from this study occurred because the experimental group was just better to begin with. However, because of this event the evidence shows positive support for answering the research questions.

Qualitative and quantitative data provided information for answering Research Question Two. The data shows that using technology in an inquiry based setting improved students' abilities to read and interpret graphs. CBL technology has been found to improve learning of students by engaging the students higher order thinking skills (Wetzel, 1999). The results demonstrated in this study indicated that hand-held technology such as CBL 2 can help improve graph interpretation skills. Such findings were in line with the literature (Svec, 1999; Mokros & Tinker, 1987; Brasell, 1987; Bernhard, 2000).

*Attitude changes motivated from technology*

From this study, the researcher was able to obtain another important finding. Students in the experimental group enjoyed using technology. This was one of the factors that lead to students showing interest in providing their own learning. There was pronounced and explicit support for technology during data collection via interviews in the research study's experimental group. Students in the experimental group demonstrated positive attitudes towards technology and were motivated. This finding is in line with the research of the National Foundation for Educational Research (NFER) that connects attitude to achievement. Such findings are in the NFER summary of the Third International Math and Science Study (TIMSS) (Ruddock et al., 2004). Findings reported in this thesis were also consistent with other literature documenting that technology contributes to the learning process by enhancing interest and motivation (Blumenfeld et al., 1991).

Individual improvement resulted from students' improved attitudes towards learning science. Students that enjoyed themselves were more attentive. Using inquiry-teaching methods integrated with technology encouraged the students to become active in their own learning. The findings from this study suggest that inquiry based teaching integrated with technology promotes higher awareness and interest in classroom learning from those students that might be termed "low achieving". Students in a traditional setting would only have intrinsic motivation helping them learn the material. Highly motivated students would do well on post-tests and not be affected by the method of teaching. Those that were low achieving find little motivational material in a traditional setting. Students in an inquiry setting are actively thinking. The effectiveness of the MBL

may result because it provides a genuine scientific experience for students to gather and analyze real data (Mokros & Tinker, 1987).

However, technology on its own is likely to be insufficient to provide motivation for students to learn. How that technology is used is also important in determining its effects on students.

It is within teachers' power to foster positive attitudes among their students. If they choose significant, accessible, and exciting topics in science and mathematics, if they feature teamwork as well as competition among students, if they focus on exploring and understanding more than the rote memorization of terms, and if they make sure all their students know they are expected to explore and learn and have their achievements acknowledged, then nearly all of those students will indeed learn (AAAS, 1989, Chapter 12 Values and Attitudes, para. 12).

Teaching methods that utilize inquiry facilitated with technology can provide the necessary stimulus needed for low achievers to experience success. Project 2061 ideology supports future research into the study of how technology acts as a motivator (AAAS, 1989); therefore, this study's findings are important.

A possible downside to having technology be a motivator is that not all students and schools have equal access. In recent years, provincial mandates have dictated that senior level mathematics courses use expensive calculator technology. Schools have been left with the difficult task of offering creative solutions to ensure that all students, privileged or not, have access to technology. Student motivation through technology use is not to be dependent on financial status.

### *Limitations*

This study was conducted with a small sample of students in the control class ( $N = 23$ ) and experimental class ( $N = 26$ ). The small sampling sizes may have resulted in providing an inadequate representation of levels of ability and cognitive development. As a result, it may be unreasonable to conclude that the findings of the study are applicable to the greater population. The intention of the findings reported were to represent what a science teacher might observe when using hand-held technology to promote inquiry.

In the pilot and study, pre and post-tests were issued a minimum of 30 days apart. However, it is possible that some students may have just remembered test items, had time to think about answers, and scored higher on the post-test given that the post-test was exactly the same as the pre-test.

Formalized measurement with respect to attitudes towards studying science using technology were not conducted. Although aspects related to attitude are mentioned in the discussion, there is no quantitative data to directly support that attitude improvement resulted from learning using an inquiry perspective or that technology use lead to those attitude changes.

Inquiry learning integrated with technology has other limitations. Technology has its difficulties. It is expensive and requires teachers to develop long term planning in order to obtain sufficient equipment for class use. In discussions with other teachers that use this form of technology, it has been determined that it is very beneficial to have more than one computer in the classroom. Most teachers have difficulty with gaining access to one computer never mind more than one computer. Availability of multiple computer

stations allow easier access for students in order to provide opportunity for data manipulation and printing during the analysis stage of scientific research.

Another limitation of this research is the length of the study. Learning from an inquiry perspective can take a great deal of time. In many instances, the inquiry class was rushed and inadequate time was available for true inquiry to occur because it was important for the researcher to keep up with the traditional class.

### *Further Research*

This study confirmed findings from the literature about the use of technology in conjunction with inquiry based learning (Edelson, Gordin, & Pea, 1999) and improving graph interpretation skills (Svec, 1999). However, it also presented several new areas that require further research. For example:

- Are the benefits of using CBL technology long lasting?
- Will the skills that the students learned be significant enough that they will benefit from them in their higher grades?
- What influence does CBL technology have on students as they think about possible futures working in the field of science?
- Were the experiences that these students had in these lessons memorable enough that they might direct their future?
- What effect does using MBL technology have on those teachers that have used it for numerous years?

No such answers to these questions are available even though investigations in MBL technologies have occurred for more than 20 years. In order to collect data to answer some of these questions, a longitudinal study would be necessary. This study would

involve tracking students and teachers who used MBL technology and inquiry learning in their classes.

Throughout the research literature on MBL technology, there are several warnings that this equipment is only a tool for learning. Teaching with MBL technology but with no sound pedagogy is only marginally better than traditional teaching; pedagogy is more important than use of technology (Bernhard, 2000). Project 2061 also reflects that one cannot just expect the technology to make a difference on its own. It does no good to argue which type of technology, hand-held or computer based is best. Technology use makes the difference.

A reasonable first step in future research would be to move away from comparing technologies or methods and begin to describe carefully the science teaching and learning situations in which technology has an impact on student performance and behavior. This research-based focus on observation, analysis, and synthesis of approaches that work would at the same time meet the need to tie technology to science content and provide science teachers with specific information about how to implement technology successfully. (AAAS, 1997, Chapter 7 The Role of Research and Evaluation, para. 1).

From this stems an idea for future research where one teaches students using a traditional approach integrated with technology and an inquiry approach using the same technology in order to further investigate the effects that technology might have on inquiry learning.

One final research consideration stems from the latter part Research Question One: If so, to what degree. It is important to not only note changes but to investigate the

effect of those changes. Although it was determined that hand-held technology can promote student learning from a guided inquiry perspective further research is necessary to determine the extent of the improvement.

### *Concluding Remarks*

In conclusion, one of the most impressive findings from this research has to do with the results obtained from the experimental class with respect to individual student improvements. The data suggested that those students that might have been classified “low achievers” did in fact experience success. Wetzel (1999) reports that learning using CBL equipment levels the educational playing field for students. Creating methods that provide an equal opportunity for all students is an idea supported by AAAS. Most high achieving students are motivated enough to overcome tedious or poor teaching practice in order to be successful and move on. Often, however, it is the student who struggles due to lack of ability in comparison to his/her peers that as educators we are to be concerned about and look to the literature to determine methodologies that provide opportunities for those students to have success.

Inquiry based methods reflect the ideals that help to create a scientifically literate individual (AAAS, 1989). They provide those skills needed for students entering a world that demands knowledge of areas of science. They assist in reaching those who need to be motivated and show that science is not static memorization of facts but a dynamic ever-changing view of the world. New habits of mind are to be created in teachers: moving away from “top down teaching” that looks upon our students as “empty vessels” waiting to be filled with knowledge. All people enter into situations with prior knowledge and

deserve to have an opportunity to share their thoughts. Students deserve to learn using authentic problems that result from the natural world (Edelson, 1998).

For the researcher, this study confirmed that one is not to teach mathematics and science as separate subjects. As emphasized in SFAA, science uses mathematics as its language and grammar (AAAS, 1989). For example, the obvious connection between these two subjects became very evident as students learned about slope. As related to temperature change, students experienced slope as rate of change and were in some cases able to express their understanding in written form. Too often, in mathematics, educators present formulae and once students can manipulate the formulae, teachers provide the application. The experimental students first exposure to slope involved application along with formula manipulation. It is the hope of this researcher that when the students learn slope in their future mathematics classes they will have a greater understanding as a result of their science experiences.

So what does the average classroom look like? Are students quietly “engaged” in the study of science as they hear opinions, take down others’ ideas through excessive note taking, and question answering? Alternatively, is there presentation of problems that are applicable to everyday situations where they might have an opinion and an inner desire to ask further questions in order to provide deeper insight and understanding? Is there integration, showing connections between other subjects so that a curricular objective that was once taught as a stale formula now has become visual and possibly rediscovered? Are all students, regardless of their achievement on some low-level rote test, being motivated to move from being passive to active?

The present study reaffirms the belief of this researcher that there is more to teaching than just “getting through the textbook”. Technology is a tool that can be effective in helping to move from the static to the dynamic world of teaching and learning. This message can never be stated better than when it comes from the mouth of one of the students in this project who stated (paraphrasing) *‘Science is when I am the scientist and is “just funner to do than sitting down writing all day”’*.

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## Appendix A: Lesson Plans

**Pre-lesson for Experimental and Control**

Objective:

1. Introduce experimental group to technology
2. Introduce control and experimental groups to graphing lines, drawing lines of best fit and finding slopes.

**Research**

GIST and TOGS tests have been given prior to start of lesson. Ethics forms are also done prior to all lessons.

**Introduction (15 minutes)**

In this chapter, we are going to look at one kind of energy, heat energy. Two terms that are often used incorrectly when discussing heat energy are heat and temperature. The following video can help explain the difference. *Watch Eureka video and have students complete the worksheet. After going over the video work on the one side of attached sheet that deals with the differences between heat and temperature.*

**Body (50 minutes)**

Also today we are going to look at are some ways to represent data. In science, you can not just make a statement. You have to back it up with facts. That is where the collecting data comes in. Being able to draw a graph, and find information from those graphs is important. Today what I would like to do is teach you a way of getting information from a graph. *Provide example of plotted data and have students draw lines of best fit and find the slopes. Provide at least three graphs.*

Since the topic we will be studying is on heat let's do some investigating using a good source of heat, our bodies.

**Experimental**

One way to collect that data is to use some technology. The technology that we are going to use is the CBL. It hooks to a graphing calculator and collects data, such as temperature readings, and stores it so that it can be transferred to a computer and creates a graph. *Divide the experimental group into groups of three by number in the students from 1 to 9 and having ones work together etc.... These groups will be the groups for the rest of the study. Set up with one temperature probe and have them collect data for 2 minutes taking a reading every 10 seconds. Get data and draw a line of best fit and find the slope. Have the students answer the following slope related question.*

**Control**

What I have here is data that represents temperature readings for 2 minutes (120 seconds) of a thermometer that I put under my arm. *For the control class have data and plot the points with them. Have them draw a line of best fit and calculate slope.*

Questions for both groups.

1. What are the units for the slope?
2. How fast did the thermometer (probe) gain energy?

**Journal questions**

Explain to the class that at the end of each class as groups they will decide which of three questions they would like to answer. Together as a group they can discuss the answer but individually must write your own response.

**Assessment:** Hand in the first three slopes and the body temperature graph.

## Experimental Lesson 1: Heat Energy

### Objectives:

1. Provide evidence to explain how an object gains heat energy using the heat transfer theory.
2. Read and interpret data from a graph that was collected using CBL 2 technology.

### Introduction:

What we know from last day is that some objects, like ourselves, give off heat. Along time ago, how heat was transferred from one object to another was explained by a Caloric Theory. This Theory said that heat was a fluid, called Caloric, that was moved from one object to another. This theory explained why heated objects expanded when heated. *Show using ring and ball apparatus.* This theory worked for awhile until someone reasoned that if an object gains something it should get heavier. After finding the mass of an object before and after heating it was found that it did not gain mass; therefore, the Caloric theory was abandoned.

If an object does not gain heat energy because of a fluid moving into it, what other explanation(s) can there be? To study another possible explanation, let's get into our groups and see if you can come up with another way of solving this question using what your group knows from your experiences with heat. *In groups of three, do a placemat to answer the questions. Have students write down their ideas in their section (give them about two minutes to think) and then have them share their ideas with in their group.*

Questions to prompt their thinking for thinking about heat energy.

- how can you transform one form of energy into heat energy?
- how can you warm an object up?
- How is heat produced?
- What causes an object to heat up?

*Go around the room and hear from each group.* The main idea that I heard from this group is that to warm something up you need movement. We are going to do an exploration to determine if movement of one particle against another transforms mechanical/vital energy to heat energy.

### Body

#### Making Thermal Energy

Purpose: To explore if movement of one object against another transfers that energy into heat energy.

Materials: Plastic foam cups, sand, CBL2, graphing calculators, computer with graphical analysis program, temperature probes.

Procedure: Page 231. Science Probe 8 BC edition 1995.

Addendums.

1. Use CBL 2 temperature probes instead of thermometers. Plug temperature probe into channel 1 on CBL 2. Connect CBL 2 and TI-83 plus and on calculator press APS and run program Datamate. Press 1: setup and select MODE: Time graph

and collect data every 30 seconds and collect it 10 times (this is equivalent to 5 minutes). Press 1 for OK. Place thermometer probe in correct position and press 2: Start. When data is finished collecting press ENTER and bring calculator to computer station to get a print out of group data. Use graphical analysis program to download data and get a print out.

2. Teacher can do shaking with no sand in cup for comparison.

Data: Part I: Rubbing hands

Situation	Observation
Rub hands for ten seconds	

Part II: Shaking sand

Graph from shaking cups for five minutes and draw a line of best fit for the data.

Shaking sand questions.

1. Reading from the graph.
  - a. What was the starting temperature of the sand?
  - b. What was the final temperature of the sand after shaking for five minutes?
  - c. What would be the temperature if you had shaken the sand for 600 seconds (10 minutes)?
  - d. How long would it take to increase the sand temperature  $6^{\circ}\text{C}$ ?
  - e. Find the slope of the line in order to determine the rate at which the sand is gaining heat energy? Do not forget to include units.
2. What was the temperature change in the plastic foam cups with no sands? Explain the result.
3. Thinking about both procedures, shaking with sand and without, what causes an object to gain heat energy?

### Conclusion

The new theory that replaced the Caloric Theory was the Heat Transfer Theory.

Heat Energy Notes:

1. Heat is not made up of particles but is a form of energy
2. Cold objects are heated by their particles moving faster and rubbing together (friction).
3. Hot objects are cooled by their particles slowing down and rubbing less frequently.
4. Heat moves from areas of high energy to areas of low energy.

### Journal

Day 1

#### Assessment:

Hand in data and questions for part I and II of exploration.

## Experimental Lesson 2: Heat Energy

### Objectives

1. Perform an experiment that determines the temperature of absolute zero from a scientific exploration perspective using CBL 2 technology.

### Introduction:

*Hand back the labs and go over problem areas with the class.*

Scientists are often presented with problems that require creative solutions. You have learned about the indirect method, which is used when you can not measure an object directly. There are many things that you can not measure directly, can anyone think of examples? (Distance to planets, mass of an atom). One example that involves heat energy is “What is the coldest temperature possible?”

Since we are in science class we should act as scientist. Today we are going to rein act an experiment and solve a problem just like scientist did many years ago.

### Body:

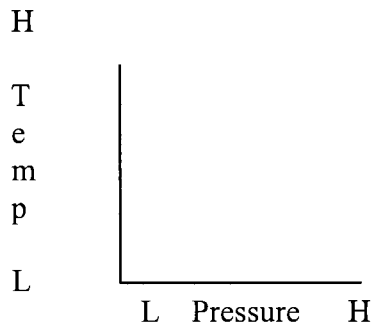
We know that when something has energy it is moving. There are three type of energy movements. I would like you to demonstrate the three types as I do them.

1. Vibrational energy: staying in one place and just vibrate
2. Rotational energy: stay in one spot but rotate along an axis, much like the Earth rotating.
3. Translational energy: you move in direction until you bounce, gently, off something and then change direction.

*Have students try out the different types as you call them out. Call more than one type and see how it goes.*

At anytime did you bump into something or some one? When molecules bump into one another they create pressure.

In your groups answer the following and be prepared to share your answers. Draw a temperature vs. pressure graph and label axis as shown:



1. If a molecule has high pressure, lots of movement, what should the temperature be? (high). Place an X where this molecule be put on the graph.
2. If a molecule has low temperature what should the pressure? (low). Place an X where this molecule be put on the graph.
3. Place an X on the graph to represent medium temperature and medium pressure.
4. Join the Xs with a line of best and extend it past the first and last X.

Where is the coldest part of the graph? Why can nothing be colder than this point? What this graph displays is how scientist determined what is called absolute zero. The

temperature on the graph that shows no movement is the coldest temperature anything can ever reach.

What we are going to do is determine that value using a similar method scientist used. *Repeat the procedure at least 3 times and average the results. Do not hand this out to the students just work through it with them for the first time. For lab procedure refer to Chemistry with CBL™ (Holmquist, Randall, Vloz, 1998)*

### Conclusion

Although we calculated different values, the value that has been calculated many times is the accepted value of -273.15. This value is also known as 0 Kelvin. How can we convert Celcius into Kelvin (add 273). How do you change Kelvin into Celcius (minus 273)

Complete the following table.

Celcius	Kelvin
100	
0	
20	293
	0

### Journal

Day 2

### Assessment

Hand in graphs, answer for determined value for absolute value and completed table.

## Experimental Lesson 3: Heat Energy

### Objectives

1. Answer a conduction related real world problem.

### Introduction:

*Hand back graphs and go over areas that the students need to improve on.*

I just got word that a local company that makes pots and pans has heard that there is a really great science class at Woodlands. They have decided to employ some of our great ways of thinking and have a question and have approached us to answer. However, we will have to present them with good evidence in order to get the million dollar contract they are offering us. The question we have to answer is...

- What is the best metal to use for the handles for their cookware set?

In groups come up with some good attributes of a handle used on a frying pan. Be prepared to share with the class. Discuss and agree that slow ability to heat up is a desirable characteristic.

### Body

Here are two metals that have been chose because they are readable available, easy to work with and most of all inexpensive aluminum and copper. Your task in your group is to determine using the CBL how you could test which metal would be the best.

*Have groups discuss and create a procedure for testing the metals as a class. A safe method is boiling water in beaker, attach metal rods to temperature probes using duct tape, start CBL 2 and place the metal rods in the boiling water with heat source removed. Collect data every 10 seconds for two minutes. Create graph using Graphical Analysis.*

Scientist have to be able to defend their claims so make sure that the data you collect helps make a good argument for which metal is best. Each group will need to create graphs that convince the group that there findings are true.

Conduction questions:

1. What is the predicted temperature of the copper, and the aluminum after 140 seconds?
2. How long would it take for each metal to heat up to 50°C?
3. Present your case in the form of a letter to the CEO. You must state which metal is the best and support your findings with data and graphs.

### Conclusion

The name that we give to how heat transfers in solids is conduction.

Notes on Conduction:

Heat moves through different states: solids, liquids, and gases, by different methods. For solids, as molecules begin to gain energy and move, they bump into one another, causing their neighbours to move. The heat energy is transferred through the solid by this method. This method of heat transfer is called conduction. Depending on the type of solid, some solids transfer heat faster than others.

*Video on conduction and accompanying worksheet*

### Journals

Day 3

**Assessment:** Hand in questions, graphs, and letter.

## Experimental Lesson 4: Heat Energy

### Objectives

1. Determine how heat moves by convection.

### Introduction

*Go over last days work and correct areas that needed improvement.*

In a room are all places in the room the same temperature? What areas do you think are the warmest? Which are the coolest? Why?

### Body:

Using a hot plate determine where the temperature is the warmest. Test the sides, underneath and above. How could you explain your results? Determine how you could use the CBL 2 temperature probe to collect data that would demonstrate that the air is heating up faster in different areas around the hot plate. (Graph the increase in the temperature probe for one minute, collecting readings every 10 seconds. Do this with two temperature probes one above and one on the side. Be about 30 cm above the heat source but in different positions.) Find slopes and explain their significance. Go over with class.

### Discussion

What is occurring when you see the squiggly lines rising above black pavement on hot summer days? Why does the “cloud” of gas fall down from the freezer portion of the refrigerator when you open the freezer door?

Ask why you would heat up a chimney in your house by holding burning newspaper in the flu before you light a fire. What might happen if you did not do this?

### Demonstration:

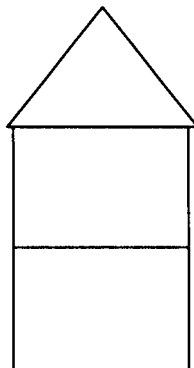
*Use glass tube, and dye demo for convection in liquids. Use chimney apparatus and flash paper to demo convection in gases. Draw diagrams using hand worksheet. Have students make predictions before demonstrating.*

Movement of heat through air and liquids is called convection.

### Notes on Convection:

Convection is the transfer of heat by the movement of either a gas (air) or a liquid (usually water). For example, air expands as it is heated and it becomes less dense and rises. The cooler air has no other place to go so it falls and replaces where the warmed air came from. This movement in air or liquids is called convection currents.

Apply what you know by designing a house’s forced air heating system. Example house:



Criteria:

1. The following items are placed in a correct position: furnace, 2 cool air vents, 2 hot air vents. (5 marks)
2. Draw cool and warm air movement (2 marks)
3. Pride in drawing and colouring. (3 marks)

Watch Eureka video reviewing convection and do question sheet.

**Journal**

Day 4

**Assessment:** Hand in house heating system drawing.

## Experimental Lesson 5: Heat Energy

### Objectives:

1. Describe how heat energy moves with respect to heat radiation.
2. Solve a problem based on the principles of radiant heat.

### Introduction:

Answer questions in your groups. Use the placemat idea. First answer singly and then combine and discuss your answers.

Questions to answer:

If you left something outside in the sun, would the colour that it is affect how hot it got? What colour would be warmest what colour would be coolest? Using your prior knowledge, give evidence that supports your conclusions. Or ask what has been your experience when walking barefoot on black top in the summer?

### Body:

What colour container, black, or white will heat up the slowest when heated by a heat source? Make a prediction and design an experiment using the CBL temperature probe. Your experiment must produce evidence that supports or rejects your purpose. Discuss a procedure as a class. *Suggested procedure is having a probe in a black test tube, probe in white test tube, have water in tubes and shine a light on the test tubes and record the change in temperature every 60 seconds (1 minute) for 600 seconds (10 minutes).*

Produce graphs and explain how the graph shows that the black tube heats up fastest. (Slope is greater).

Show Radiation video and worksheet while the data is being collected.

Radiation questions:

1. What would be the predicted temperature after 900 seconds (15 minutes)?
2. How long would it take for the temperature in each of the test tubes to heat up to 60°C?
3. From your graph what tells you that the black tube is gaining heat faster? Explain.

### Conclusion:

This form of heat transfer is called radiation.

Notes on Heat Radiation

Radiation is how heat energy is transferred from hot objects to colder objects but not by conduction or convection. Heat moving when there are no molecules, such as heat we receive from the Sun, is transferred by heat radiation.

Heat radiation moves in waves.

### Journals:

Day 5

**Assessment:** Radiation lab

## Experimental Lesson 6 & 7: Heat Energy

### Objective:

1. Apply principles of heat energy to create an insulated object.

### Introduction:

In groups (placemat) determine what are some characteristics used by a thermos to keep something hot or something? Knowing about conduction, convection, and heat radiation, explain what features of your thermos are stopping heat from being transferred.

### Body:

Design an experiment, using the CBL temperature probe, to determine how much faster boiling water cools in a non insulated metal can as compared to the can you designed to keep heat from being lost. Support your finding with graphs.

Students should be guided to test a non insulated can by adding boiling hot water and then time the rate of cooling for 10 minutes (600 seconds).

On day 1, students should test their non insulated cans and build their insulated can for testing the next day. (Students should have been told to bring material for building and insulated container on day 5) On day 2, students will test thermos and get notes on insulation (and also do the GIST and TOGS).

Insulator lab questions.

1. At the rate of cooling for the insulated can and non insulated can what would be the expected temperature after 15 minutes?
2. How long would it take for water to get to 50°C for both cans?
3. What is the rate at which the non insulated and insulated cans are losing heat?

### Conclusion:

Class discussion

How is heat transfer by conduction slowed by an insulator?

How is heat transfer by convection slowed by an insulator?

How is heat transfer by radiation slowed by an insulator?

Notes on insulators

Insulation, or insulators, slow down the transfer of heat. A good insulator attempts to reduce heat transfer by conduction, convection, and radiation. A good way to prevent heat loss is to trap air. In air, molecules are far apart so conduction is very slow. Air trapped in small pockets prevents movement and therefore heat loss by convection does not occur. Finally, using material that reflects, can reflect heat transferred by radiation.

Follow up questions.

Which way do you put aluminum foil wrap when try to bake something?

How can curtains help keep your house warm in winter?

### Journals:

Day 6 & 7

### Assessment

Hand in insulator lab

### Research:

On day 2 of this lesson students should write the GIST and TOGS.

## Traditional Lesson 1: Heat Energy

### Objectives:

1. Provide evidence to explain how an object gains heat energy using the heat transfer theory.
2. Read and interpret data from a hand constructed graph .

### Introduction:

What we know from last day is that some objects, like ourselves, give off heat. Along time ago, how heat was transferred from one object to another was explained by a Caloric Theory. This Theory said that heat was a fluid, called Caloric, that was moved from one object to another. This theory explained why heated objects expanded when heated. *Show using ring and ball apparatus.* This theory worked for awhile until someone reasoned that if an object gains something it should get heavier. After finding the mass of an object before and after heating it was found that it did not gain mass; therefore, the Caloric theory was abandoned.

The new theory that replaced the Caloric theory was the Heat Transfer theory.

### Notes

#### Heat transfer theory.

1. Heat is not made up of particles but is a form of energy
2. Cold objects are heat by their particles moving faster and rubbing together (friction).
3. Hot objects are cooled by their particles slowing down and rubbing less frequently.

### Body

To verify how heat can be transferred the following lab will be done.

#### Making Thermal Energy

**Purpose:** To verify that mechanical (movement) energy can create heat energy.

**Materials:** Plastic foam cups, sand, thermometers, graph paper.

**Procedure:** Page 231. Science Probe 8 BC edition 1995.

#### Addendums.

1. Graph the data in part II
2. Teacher can do shaking with no sand in cup for comparison.

#### Data:

##### Part I: Rubbing hands

Situation	Observation
Rub hands for ten seconds	

##### Part II: Shaking sand

Time (minutes)	Temperature (°C)
1	
2	
3	
4	
5	

Graph the data for shaking the cups for five minutes and draw a line of best fit for the data.

Questions

4. Reading from the graph.
  - a. What was the starting temperature of the sand?
  - b. What was the final temperature of the sand after shaking for five minutes?
  - c. What would be the temperature if you had shaken the sand for 600 seconds (10 minutes)?
  - d. How long would it take to increase the sand temperature  $6^{\circ}\text{C}$ ?
  - e. Find the slope of the line in order to determine the rate at which the sand is gaining heat energy? Do not forget to include units.
5. What was the temperature change in the plastic foam cups with no sands? Explain the result.
6. Thinking about both procedures, shaking with sand and without, what causes an object to gain heat energy?

**Journal**

Day 1

**Assessment:**

Hand in data and questions for part I and II of exploration.

## Traditional lesson 2: Heat Energy

### Objectives

1. Perform an experiment that determines the temperature of absolute zero from a scientific exploration perspective using CBL 2 technology.

### Introduction:

*Hand back the labs and go over problem areas with the class.*

Scientists are often presented with problems that require creative solutions. For example how can one find the distance to planets when you can not travel there? Or what is the mass of an atom, knowing that we can not just put it on a balance and find its mass directly. We have studied the indirect method so let's use that idea and see if we can recreate how scientists solved a question about heat energy.

Since we are in science class we should act as scientist. Today we are going to rein act an experiment and solve a problem just like scientist did many years ago.

We know that when something has energy it is moving. There are three type of energy movements. I would like you to demonstrate the three types as I do them.

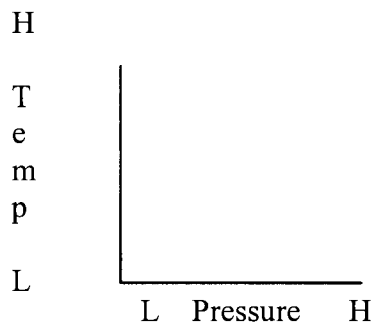
### Notes

1. Vibrational energy: staying in one place and just vibrate
2. Rotational energy: stay in one spot but rotate along an axis, much like the Earth rotating.
3. Translational energy: you move in direction until you bounce, gently, off something and then change direction.

*Have students try out the different types as you call them out. Call more than one type and see how it goes.*

Settle the class and ask, "At anytime did you bump into something or some one? When molecules bump into one another they create pressure.

*As a class and in the form of notes draw a temperature vs. pressure graph and label axis as shown:*



1. If a molecule has high pressure, lots of movement, what should the temperature be? (high). Place an X where this molecule be put on the graph.
2. If a molecule has low temperature what should the pressure? (low). Place an X where this molecule be put on the graph.
3. Place an X on the graph to represent medium temperature and medium pressure.
4. Join the Xs with a line of best and extend it past the first and last X.

What this graph displays is how scientist determined what is called absolute zero. The temperature on the graph that shows no movement is the coldest temperature anything can ever reach. This temperature is  $-273.15^{\circ}\text{C}$ .

### Body

Use the following data points, create a graph and verify the value of absolute zero, by connecting the points using a line of best fit and seeing where the graph crosses the y axis. Where the graph crosses the y axis (temperature scale) tells us the absolute coldest temperature. Repeat this for all three sets of data and find the average.

Data points

Pressure (kpa)	Temperature ( $^{\circ}\text{C}$ )
96	0
102	19
110	44
130	99

Pressure (kpa)	Temperature ( $^{\circ}\text{C}$ )
99	2
104	21
113	60
124	72

Pressure (kpa)	Temperature ( $^{\circ}\text{C}$ )
100	6
106	22
115	62
128	85

### Conclusion

This value is also known as 0 Kelvin. To convert Celcius into Kelvin add 273. To change Kelvin into Celcius minus 273.

Complete the following table.

Celcius	Kelvin
100	
0	
20	293
	0

### Journal

Day 2

### Assessment

Hand in graphs, answer for determined value for absolute value and completed table.

## Traditional Lesson 3: Heat Energy

### Objectives

1. Answer a conduction related real world problem.

### Introduction:

*Go over last days work and correct areas that needed improvement.*

Today's topic is conduction.

Notes on Conduction:

Heat moves through different states: solids, liquids, and gases, by different methods. For solids, as molecules begin to gain energy and move, they bump into one another, causing their neighbours to move. The heat energy is transferred through the solid by this method. This method of heat transfer is called conduction. Depending on the type of solid, some solids transfer heat faster than others.

I just got word that a local company that makes pots and pans has heard that there is a really great science class at Woodlands. They have decided to employ some of our great ways of thinking and have a question and have approached us to answer.

- What is the best metal to use for the handles for their cookware set.

What are good characteristics for a frying pan handle? Discuss as a class.

### Body

Here are two metals that have been chose because they are readable available, easy to work with and most of all inexpensive: Aluminum and copper. Our task is to determine the rates at which the metals heat up.

*Test the metals using paper clips attached to the different metals by wax and place them in hot water.*

The following created data verifies the observation that we just saw. Plot the data, determine the slopes (rates). Hand out data for plotting. The steeper the slope the faster the metal heats up.

Time (seconds)	Copper (°C)	Aluminum (°C)
0	20	20
20	25	24
40	31	27
60	38	31
80	43	37
100	48	39

### Conclusion

Video on conduction and accompanying worksheet

### Journals

Day 3

**Assessment:** Hand in plotted graphs with slopes calculated and explanations.

## Traditional lesson 4: Heat Energy

### Objectives

1. Determine how heat moves by convection.

### Introduction

In a room not all areas are the same temperature. Ceilings are warmest and floors are coolest. This occurs because heated air moves by convection.

### Notes

Convection is the transfer of heat by the movement of either a gas (air) or a liquid (usually water). For example, air expands as it is heated and it becomes less dense and rises. The cooler air has no other place to go so it falls and replaces where the warmed air came from. This movement in air or liquids is called convection currents.

### Body:

#### *Demonstrate convection:*

Use a hot plate to show that the heat rises

Use glass tube, and dye demo for convection in liquids. Use chimney apparatus and flash paper to demo convection in gases. Draw diagrams using hand worksheet.

#### *Discussion:*

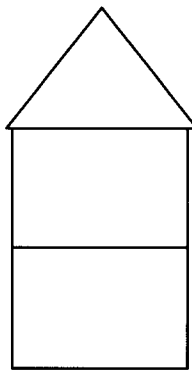
Explain why you see the squiggly lines rising above black pavement on hot summer days?

Explain why a “cloud” of gas falls down from the freezer portion of the refrigerator when you open the freezer door?

Discuss why you would heat up a chimney in your house by holding burning newspaper in the flu before you light a fire. What might happen if you did not do this?

Watch Eureka video on convection and do question sheets.

Use the example of hot air heating system in video to have students draw a house's forced air heating system. Example house:



#### Criteria:

1. The following items are placed in a correct position: furnace, 2 cool air vents, 2 hot air vents. (5 marks)
2. Draw cool and warm air movement (2 marks)
3. Pride in drawing and colouring. (3 marks)

### Journal

Day 4

**Assessment:** House heating system design.

## Traditional Lesson 5: Heat Energy

### Objectives:

1. Describe how heat energy moves with respect to heat radiation.

### Introduction:

Questions

Discuss as a class:

If you left something outside in the sun, would the colour that it is affect how hot it got? What colour would be warmest what colour would be coolest? Or what happens when you walk on black top on a hot summer day?

Heat transferred in this form is called radiation.

Notes

Radiation is how heat energy is transferred from hot objects to colder objects but not by conduction or convection. Heat moving when there are no molecules, such as heat we receive from the Sun, is transferred by heat radiation.

### Body:

As a class collect data by filling in the data sheet and plot the data (see attached lab worksheet). Collect the temperature increase in black test tube using a thermometer and a white test tube using a thermometer. Use a heat lamp as a source for heat radiation. Collect the data for 10 minutes and draw a graph. Have the students plot the points as the data is being collected.

Using the graph answer the following:

1. What would be the predicted temperature after 900 seconds (15 minutes)?
2. How long would it take for the temperature in each of the test tubes to heat up to 60°C?
3. From your graph what tells you that the black tube is gaining heat faster? Explain.

### Conclusion:

Video on radiation and worksheet.

### Journals:

Day 5

### Assessment:

Hand in lab

## Traditional Lesson 6 & 7: Heat Energy

### Objective:

1. Apply principles of heat energy to create an insulated object.

### Introduction:

Notes

Insulation, or insulators, slow down the transfer of heat. A good insulator attempts to reduce heat transfer by conduction, convection, and radiation. A good way to prevent heat loss is to trap air. In air, molecules are far apart so conduction is very slow. Air trapped in small pockets prevents movement and therefore heat loss by convection does not occur. Finally, using material that reflects, can reflect heat transferred by radiation.

### Body:

On day 1, students should test their non insulated cans and build their insulated can for testing the next day. (Students should have been told to bring material for building and insulated container on day 5) On day 2, students will test thermos and get notes on insulation (and also do the GIST).

See attached worksheet called "Building an Insulated Thermos." The one addition is that students should plot graphs for part I and II data.

Graphing follow up.

At the rate of cooling for the insulated can and non insulated can what would be the expected temperature after 15 minutes? How long would it take for water to get to 50°C for both cans?

### Conclusion:

Class discussion

How is heat transfer by conduction slowed by an insulator?

How is heat transfer by convection slowed by an insulator?

How is heat transfer by radiation slowed by an insulator?

Follow up questions.

Which way do you put aluminum foil wrap when try to bake something?

How can curtains help keep your house warm in winter?

### Journals:

Day 6 & 7

### Assessment

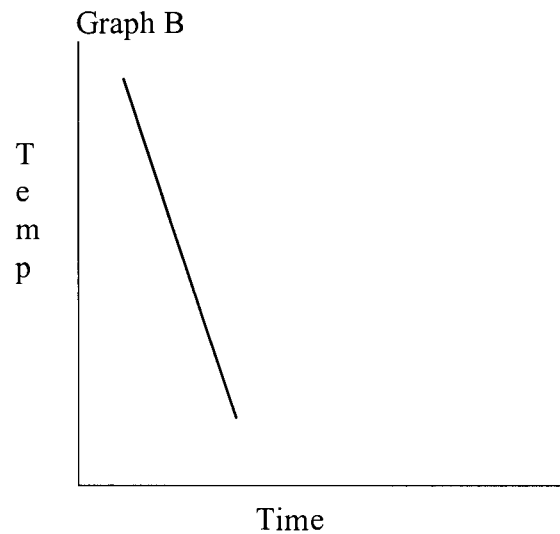
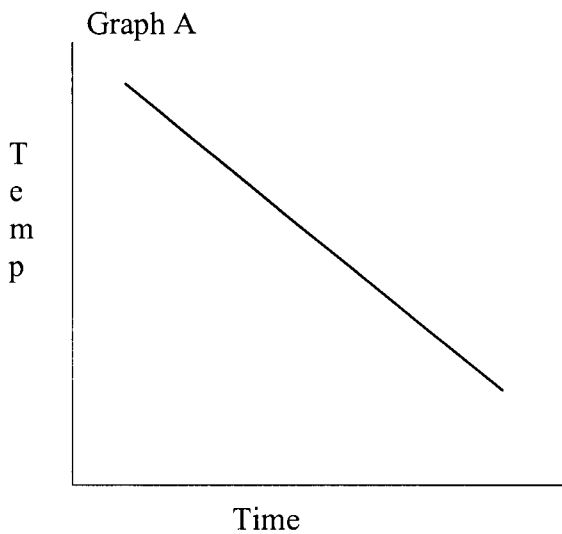
Hand in insulator lab

Research:

On day 2 of this lesson students should write the GIST.

## Appendix B: Interview questions

1. What part(s) of the classes (lessons) did you enjoy? and what part(s) of the lesson did you not enjoy?
  - why did you enjoy these parts?
  - why did you not enjoy these parts?
  
2. In this class do you feel that you are doing your own learning or is the teacher providing the learning?
  - who is asking the questions (teacher or students)?
  - who is providing the answers to the questions (teacher or students)?
  
3. I need your help to solve a problem. I have mixed up two coffee cups one has a lot of sugar in it and the other has no sugar. They are for some company so I do not want to taste them to tell which is which. However, I have heard that liquids cool slower when they have things like sugar dissolved in them. From this information, please tell me a method to solve this problem and what sort of data could I collect and display to answer this question?
  - I have two graphs of data that were collected, which one belongs to the cup with sugar in it (or with out sugar in it)? Explain to me your choice.



4. In the pretest you got this # question incorrect but after the lesson you got the same # question correct. Why do you think that you were able to get that question correct now?

## Appendix C: Journal questions

After each day, students in the experimental group will be put in a group of three and together decide what question (1, 2, or 3) the group will choose. The group will discuss the question and then independently write their response. The control group will be treated in the same fashion.

Pre lesson: (not used in the study)

1. What was the starting temperature and the final temperature for your graphed data? Use full sentences to answer.
2. Where did the heat come from to cause the temperature to rise? Explain using complete sentences.
3. If you had just come in from a run would you expect the slope of the graph to be greater (steeper), flatter (less steep), or same as the slope you calculated in class? Explain your answer.

Day 1: Generating Heat energy

1. How could you convince someone that movement generates heat?
2. What was today's big idea? How did you learn this big idea?
3. If you shook the container faster, how would the slope of the graph have changed? Explain.

Day 2: Determining the value of absolute zero

1. What is the coldest temperature? Why is the name absolute zero a good name for this coldest temperature?
2. How does the graph show that nothing can get colder than absolute zero?
3. It is impossible to get to absolute zero. Argue that this is a true or false statement.

Day 3: Conduction

4. Gold is a better conductor than copper. Use a graph to show what the slope of gold would look like compared to copper.
5. Define 'conduction' in your own words. Use full sentences.
6. Give an example of where conduction could be applied in your daily life.

Day 4: Convection

1. Explain why it is very hard to keep your basement warm in winter.
2. Is it better to put a heating vent in the floor or in the ceiling of your house? Explain
3. Using complete sentences answer: In what state(s) (solid, liquid, gas) does convection occur? In what state(s) does conduction occur?

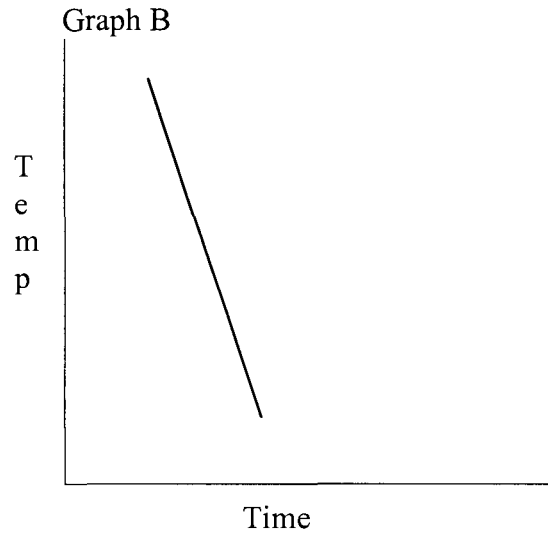
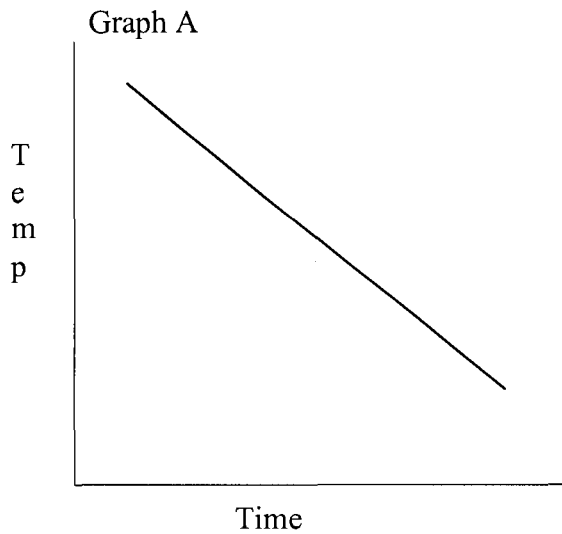
Day 5: Heat radiation

1. Do you think a silver (metal coloured) tube would absorb heat or reflect heat? How could you test your prediction.
2. Using complete sentences answer: What colour clothing should you wear on a cool day? And what colour clothing should you wear on a hot day?

3. You are employed by NASA to decide what would be the best colour for their new "Mission to Mars" space suits. Your two choices are red and blue. Create a graph of your made up data that supports your choice of colour.

Day 6 and 7: Insulation

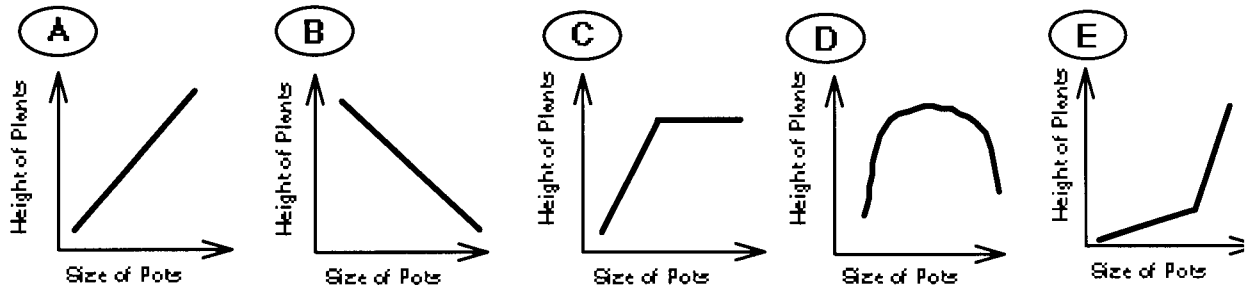
1. How could you test if a material is a good conductor of heat or a good insulator of heat.
2. List items in your house that are used to insulate it from the cold .
3. One of the following graphs represents an insulator and one represents a conductor of heat. Match the graphs and explain why you chose that graph.



## Appendix D: GIST and TOGS Instruments

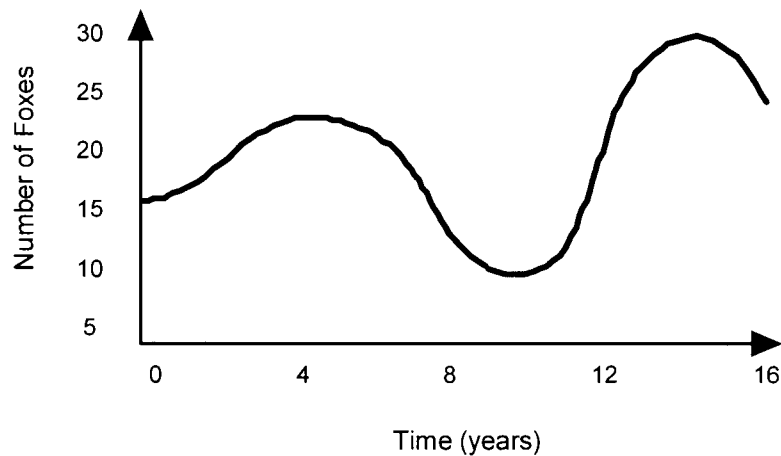
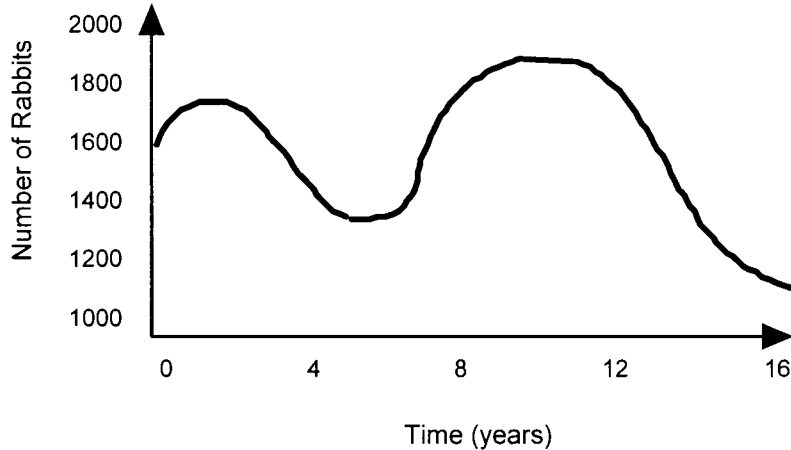
**Graphing Interpretation Skills Test (GIST)**

•Zach plans to study how well sunflowers grow in different size pots. The graph below show four possible outcomes of his experiment. Which graph is **best** described by the following statements:



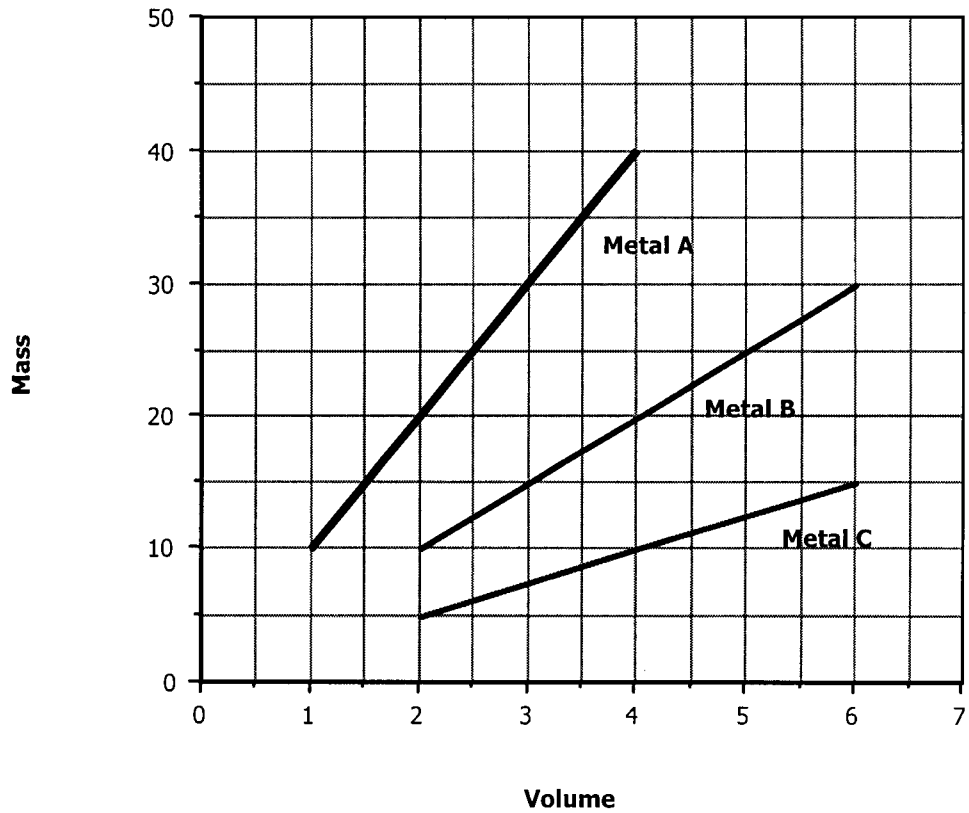
1. As the pot sizes increase, the plant height goes down.
2. As the pot size increases, the plant height increases up to a certain pot size. With larger pots, plant height remains the same.

•A scientist was interested in the number of foxes and rabbits living in a valley. She counted their numbers many times over twenty years. A copy of her graphed results is shown below.



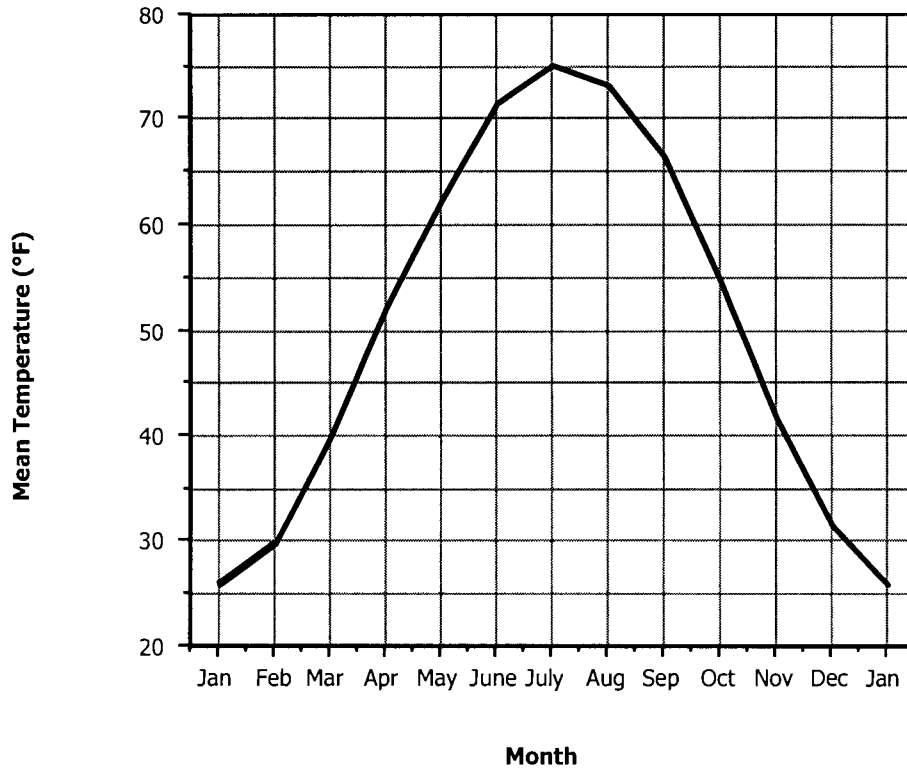
3. Which of these statements is supported by the **two** graphs?
- The number of rabbits and foxes increase at the same time.
  - During the 6th year there are more foxes in the area than rabbits.
  - There were the greatest number of foxes and the fewest rabbits at the 6th year point.
  - An increase in the number of rabbits is followed within a few years by an increase in the number of foxes.

•The density of a metal is the ratio of mass divided by volume. An experiment was set up to measure the density of three metals. For several different masses of the same metal, the volume it occupied was measured. These were plotted on the graph below.

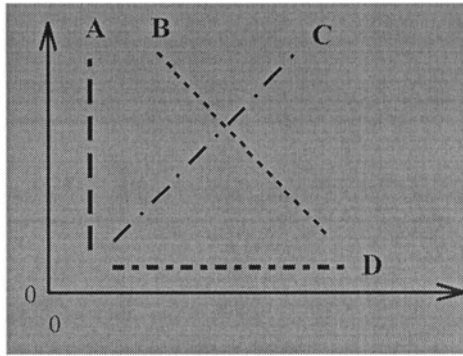


4. What is the slope for the line for Metal A?
  - a. 0.10
  - b. 3.0
  - c. 10.0
  - d. 30.0
  
5. Which metal has the smallest density?
  - a. metal A
  - b. metal B
  - c. metal C
  - d. all the same

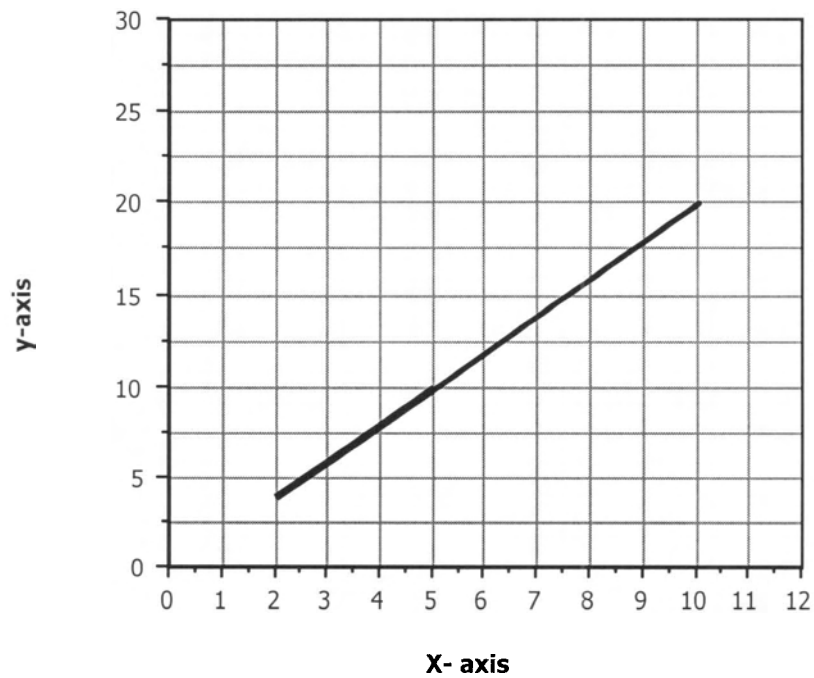
- The following graph shows the change in the monthly mean temperature for Indianapolis for a year. Answer the following questions about the graph.



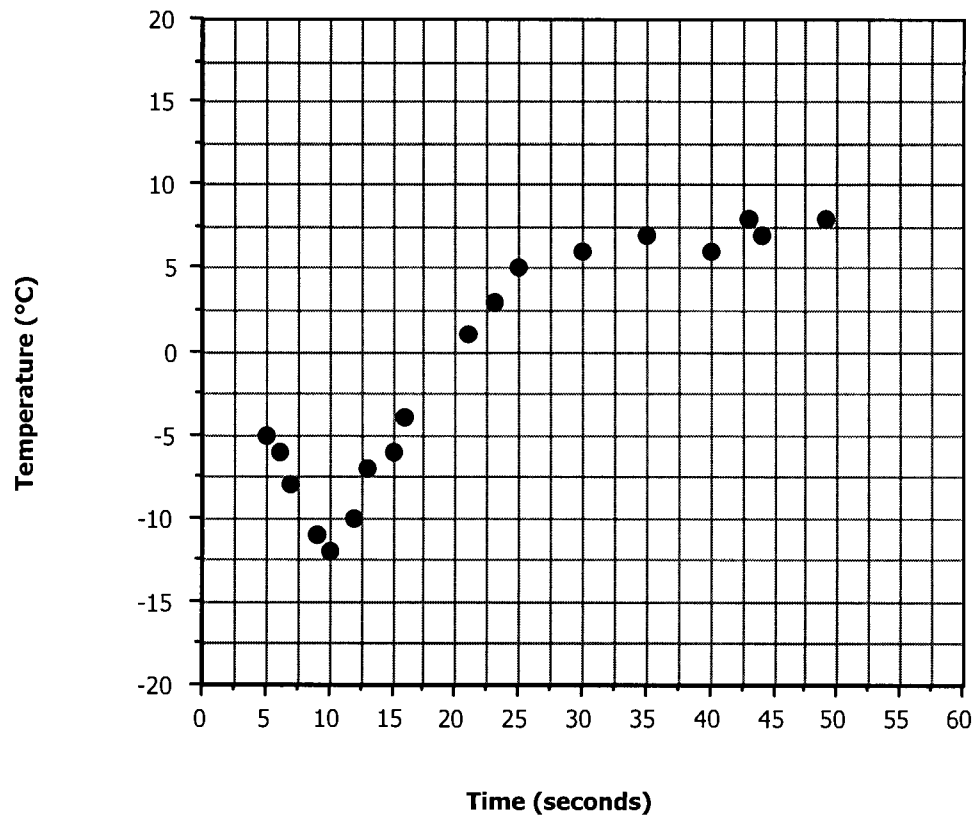
6. During what time interval was the largest temperature change?
- Jan to Feb
  - Apr to May
  - June to July
  - July to Aug
  - none is correct
7. During what interval was the rate of the temperature change most nearly constant?
- Jan to Mar
  - Mar to May
  - June to Aug
  - July to Sept
  - none is correct



8. Which line in the graph above has a slope of **zero**?
- A
  - B
  - C
  - D
  - A and D
  - none is correct

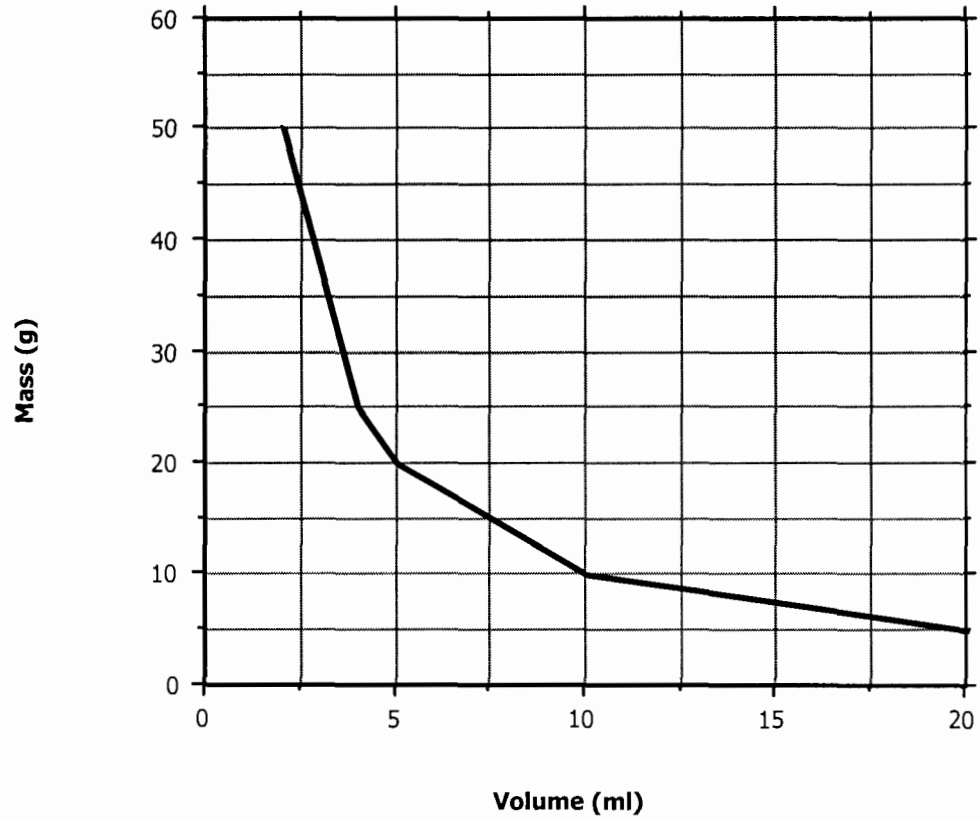


9. Calculate the slope for the graph above.
- 0.5
  - 2.0
  - 8.0
  - 16.0
  - none is correct



10. What was the coldest temperature?
- 15
  - 12
  - 5
  - 0
  - 8
11. What was the temperature at time = 19 seconds
- 5
  - 0
  - 5
  - 20

- The following graph shows the relationship between the mass and volume of a gas. Answer the following question about the graph.

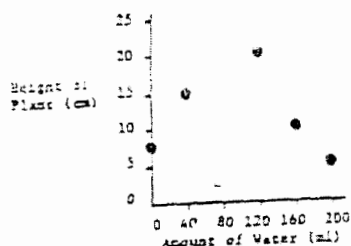


12. If you were to increase the volume by 2 ml, where would you expect the largest change in mass.
- a. around 40 g
  - b. around 20 g
  - c. around 15 g
  - d. around 7.5 g
  - j. none of the options is correct

### Test of Graphing in Science (TOGS)

Use the information below to answer questions 1-4

Rose owns a flower shop. She gave different amounts of water to several plants each day. She measured the height of the plants after three weeks. The graph below shows the results.

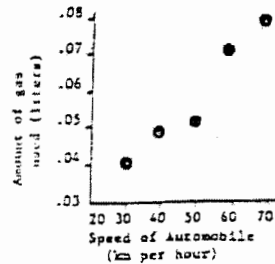


1. One plant was given 140 ml of water daily for three weeks. What would be the expected height of this plant at that time?
- 11 cm
  - 16 cm
  - 20 cm
  - 23 cm
2. How much water was given each day to the plant that grew 10 cm tall?
- 120 ml
  - 140 ml
  - 160 ml
  - 180 ml
3. The following statements describe the relationship between the amount of water given and the height of the plant. Which is the best description?
- As the amount of water increased to 120 ml, the height of the plants decreased. With amounts greater than 120 ml the height of the plants increased.
  - Both the amount of water and the height of the plants increased up to 120 ml. Then they both decreased.
  - As the amount of water increased to 120 ml the plant growth quickly increased. After 120 ml of water the plant growth increased more slowly.
  - As the amount of water increased to 120 ml the height of the plants increased. With amounts greater than 120 ml the height of the plants decreased.
4. How tall would you expect plants to grow if given 200 ml of water each day?
- less than 5 cm
  - 8 cm
  - 10 cm
  - more than 20 cm

Questions 5-8 refer to the following investigation.

5-B

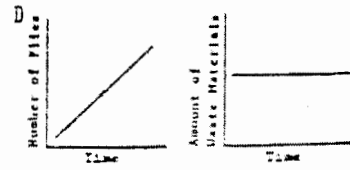
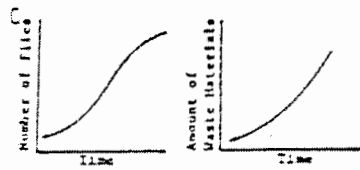
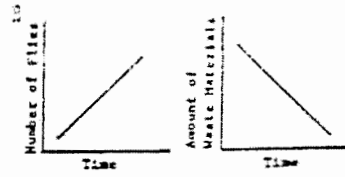
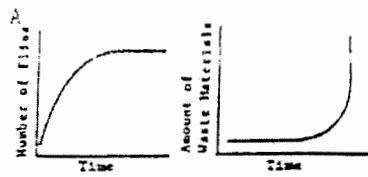
Lynn measured the amount of gas needed to drive one km at different speeds. Her results are plotted below.



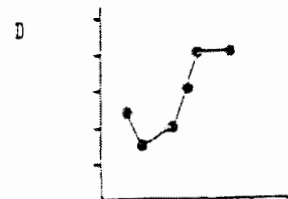
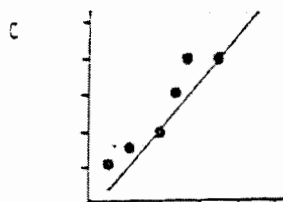
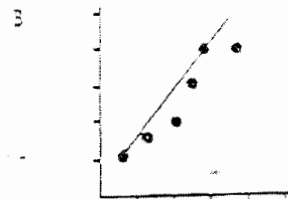
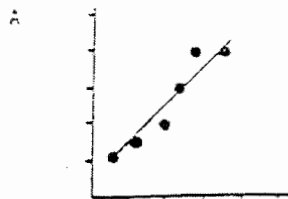
5. How much gas (liters) was used to drive one km at 60 km per hour?
- .05
  - .06
  - .07
  - .08
6. Which of the following is the best description of the relationship shown on the graph?
- As the speed of the car increases, the amount of gas used also increases.
  - As the speed of the car decreases, the amount of gas used increases.
  - The amount of gas used increases as the speed of the car decreases.
  - The amount of gas used decreases as the speed of the car increases.
7. At 55 km per hour, how much gas (liters) would the car use?
- .04
  - .05
  - .06
  - .07
8. At 80 km per hour, how much gas (liters) would the car use?
- .07
  - .08
  - .09
  - .10

9. Anne studied fruit flies for one month. She measured the amount of waste produced by the fruit flies. She concluded that as the number of flies increased, the amount of waste increases.

Which pair of graphs best support her conclusion?

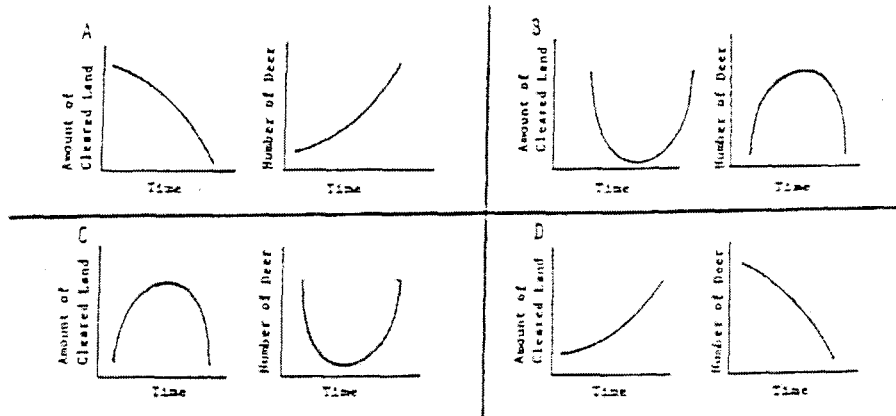


10. A best fit line describes the trend in a set of data points. Which of these graphs shows the most appropriate best fit line?

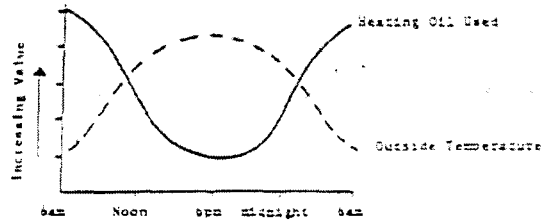


11. Jim studied the effect that clearing land has on the number of deer. Every year for 10 years he measured the amount of cleared land and the number of deer in an area. He found that the amount of cleared land increased and the number of deer decreased.

Which pair of graphs best support his conclusion?



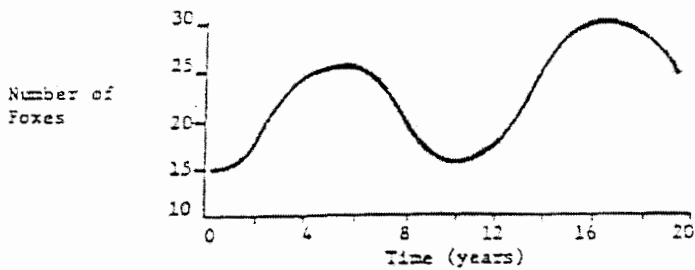
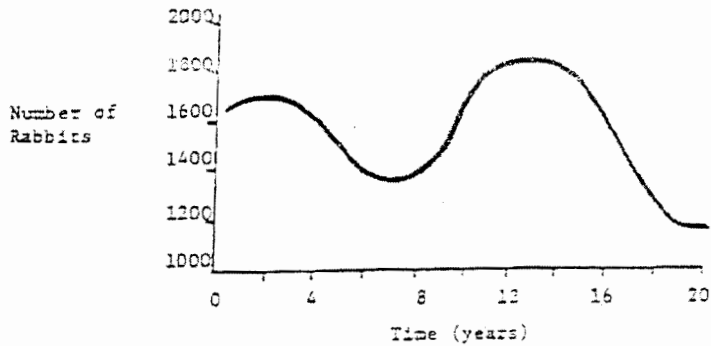
12. Tom wanted to know how the amount of heating oil needed to heat a large school was affected by the outside temperature. He measured the amount of heating oil used each hour for 24 hours. The school was kept at 20°C. He also took the outside temperature each hour. His results are graphed below.



Which of these statements is supported by the graph?

- A. As the outside temperature rises, the amount of heating oil used increases.
- B. As the outside temperature falls, the amount of heating oil used decreases.
- C. When the outside temperature stays the same, the amount of heating oil used decreases slightly.
- D. As the outside temperature rises, the amount of heating oil used decreases.

13. A scientist was interested in the number of foxes and rabbits living in a valley. She counted their numbers many times over twenty years. A copy of her graphed results is below.

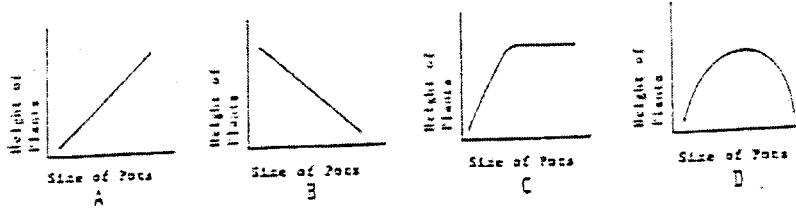


Which of these statements is supported by the two graphs?

- The number of rabbits and foxes increases at the same time.
- During the 6th year there are more foxes in the area than rabbits.
- There were the greatest number of foxes and the fewest rabbits at the six year point.
- An increase in the number of rabbits is followed within a few years by an increase in the number of foxes.

Use the following information to answer questions ~~14~~ and ~~15~~.  
 14 15

Dick plans to study how well sunflowers grow in different size pots. The graphs below show four possible outcomes of his experiment.



Which graph is best described by the following statements.

14 ~~14~~. As the pot size increases, the plant height decreases.

15 ~~15~~. As the pot size increases, the plant height increases up to a certain pot size. With larger pots, plant height remains the same.

## Appendix E: Ethics Consent Form Letter

### Using CBL Technology to Promote Inquiry and to Improve Graph Interpretation Skills in High School Science.

Your child is invited to participate in a study entitled “**Using CBL Technology to Promote Inquiry and to Improve Graph Interpretation Skills in High School Science.**” that is being conducted by \_\_\_\_\_ (teacher at \_\_\_\_\_). \_\_\_\_\_ is a graduate student in the Department of Curriculum and Instruction, Faculty of Education at the University of Victoria and you may contact him if you have further questions by calling \_\_\_\_\_ Secondary school at \_\_\_\_\_ (email \_\_\_\_\_).

As a graduate student, Mr. \_\_\_\_\_ is required to conduct research as part of the requirements for his master’s degree in science education. It is being conducted under the supervision of Dr. \_\_\_\_\_. You may contact his supervisor at \_\_\_\_\_ (email \_\_\_\_\_).

The purpose of this research project is to:

1. collect data in order to determine if calculator-based laboratory (CBL) technology improves students’ ability to interpret graphs.
2. collect data in order to determine if calculator-based laboratory (CBL) technology can be used to facilitate the learning of science from a guided inquiry, hands-on perspective.

Research of this type is important because it provides answers to questions such as:

1. How can one increase graph interpretation skills?
2. Can a method of inquiry be used to learn science?

Your child is enrolled in a science class that will be involved in a study answering the above-stated research questions.

If you agree to have your child voluntarily participate in this research, he/she will participate in a pre- and post-test involving interpretation of graphed data, writing a journal, possibly being videotaped and individually interviewed by the researcher in order to collect data to answer the above-stated questions. As a class, the students will be observed for signs of inquiry-based learning methods. No data collected from this research will be incorporated into your student’s grade; all data is for research purposes.

In this study, by giving your consent, your child may be videotaped and/or interviewed. By giving consent your child’s pre- and post-test data and journal data will be used to answer the research questions.

All students will participate in pre & post testing and all class assignments. To protect the anonymity of the students, a neutral third party will remove those individuals’ tests where consent has not been given. Also, individuals to be interviewed will be selected with the help of a third party. All interviews will occur outside of school hours, as those being interviewed will be clearly identified as participating in the study.

Participation in this study may cause no inconvenience to your child. Your child will be achieving the same learning outcomes as other science students. They will just achieve them using another means of teaching. There are no known or anticipated risks to the student by participating in this

