

5-2011

## Using graphs to represent physical phenomena in a fourth grade classroom

Mehmet Fatih Dulger  
*University of Nevada, Las Vegas*

Follow this and additional works at: <https://digitalscholarship.unlv.edu/thesesdissertations>



Part of the [Curriculum and Instruction Commons](#), [Instructional Media Design Commons](#), and the [Science and Mathematics Education Commons](#)

---

### Repository Citation

Dulger, Mehmet Fatih, "Using graphs to represent physical phenomena in a fourth grade classroom" (2011). *UNLV Theses, Dissertations, Professional Papers, and Capstones*. 1040.  
<http://dx.doi.org/10.34917/2430091>

This Thesis is protected by copyright and/or related rights. It has been brought to you by Digital Scholarship@UNLV with permission from the rights-holder(s). You are free to use this Thesis in any way that is permitted by the copyright and related rights legislation that applies to your use. For other uses you need to obtain permission from the rights-holder(s) directly, unless additional rights are indicated by a Creative Commons license in the record and/or on the work itself.

This Thesis has been accepted for inclusion in UNLV Theses, Dissertations, Professional Papers, and Capstones by an authorized administrator of Digital Scholarship@UNLV. For more information, please contact [digitalscholarship@unlv.edu](mailto:digitalscholarship@unlv.edu).

USING GRAPHS TO REPRESENT PHYSICAL PHENOMENA IN A FOURTH  
GRADE CLASSROOM

by

Mehmet Fatih Dulger

Bachelor of Science  
Middle East Technical University  
2007

A thesis submitted in partial fulfillment  
of the requirements for the

**Master of Science in Curriculum and Instruction**  
**Department of Curriculum and Instruction**  
**College of Education**

**Graduate College**  
**University of Nevada, Las Vegas**  
**May 2011**

Copyright by Mehmet Fatih Dulger 2011  
All Rights Reserved



THE GRADUATE COLLEGE

We recommend the thesis prepared under our supervision by

**Mehmet Fatih Dulger**

entitled

**Using Graphs to Represent Physical Phenomena in a Fourth Grade Classroom**

be accepted in partial fulfillment of the requirements for the degree of

**Master of Science in Curriculum & Instruction**

Hasan Deniz, Committee Chair

Kent Crippen, Committee Member

Janelle Bailey, Committee Member

Scott Joe, Graduate Faculty Representative

Ronald Smith, Ph. D., Vice President for Research and Graduate Studies  
and Dean of the Graduate College

**May 2011**

## ABSTRACT

### **Using Graphs to Represent Physical Phenomena in a Fourth Grade Classroom**

by

Mehmet F. Dulger

Dr. Hasan Deniz, Committee Chair  
Associate Professor of Science Education  
University of Nevada, Las Vegas

This study examined to what extent inquiry-based instruction supported with real-time graphing technology improves fourth grader's ability to interpret graphs as representations of physical science concepts such as motion and temperature. This study also examined whether there is any difference between inquiry-based instruction supported with real-time graphing software and inquiry-based instruction supported with traditional laboratory equipment in terms of improving fourth graders' ability to interpret motion and temperature graphs. Results of this study showed that there is a significant advantage in using real-time graphing technology to support fourth graders' ability to read and interpret graphs.

## ACKNOWLEDGEMENTS

First and foremost I offer my sincerest gratitude to my advisor, Dr. Hasan Deniz, who has supported me throughout my thesis with his patience and knowledge. With his guidance and level of support, it would not get any easier. Also, I thank to members of my thesis committee to Dr. Janelle Bailey for her valuable comments and suggestions and especially thank to Dr. Kent Crippen for giving me clear and concise directions how to tackle some editing and conceptual framework problems. Also, I would like to thank to my family for their never ending support throughout my career. Lastly, I offer my regards and blessings to all of those who supported me in any respect during the completion of the thesis.

## TABLE OF CONTENTS

ABSTRACT.....	iii
ACKNOWLEDGEMENTS.....	iv
CHAPTER 1 INTRODUCTION .....	1
CHAPTER 2 REVIEW OF THE LITERATURE .....	5
Microcomputer-Based Labs and Students' Understanding of Scientific Concepts .....	5
Summary .....	18
Teachers' Beliefs and Perspective with Regard to MBLs .....	19
Summary .....	26
Design and Integration of Microcomputer-Based Labs .....	26
Summary .....	35
Graph Reading and Interpretation Ability of Students with Microcomputer-Based Laboratories .....	36
Summary .....	44
Conclusion.....	45
CHAPTER 3 METHODOLOGY .....	49
Participants .....	49
Intervention .....	49
Technology Group.....	50
Motion Lesson .....	50
Temperature .....	51
Conventional Group .....	53
Motion Lesson .....	53
Temperature Lesson.....	55
Data Collection.....	57
Data Analysis .....	58
CHAPTER 4 RESULTS .....	59
Discussion.....	61
Limitations of the Study .....	63
APPENDIX A 5-E LEARNING CYCLE LESSON PLAN FORMAT OF MOTION AND TEMPETATURE LESSON .....	65
APPENDIX B TECHNOLOGY AND CONVENTIONAL GROUP MOTION LESSON APPLICATION QUESTIONS .....	67
APPENDIX C PRETEST AND POSTTEST QUESTIONS .....	69

REFERENCES .....	74
VITA .....	77



## CHAPTER 1

### INTRODUCTION

Technology is used everywhere these days. We are living in the information age and it is demanding learners to be able to understand and use proper technology components and devices to accomplish desired goals. According to the Pew Internet & American Life Project (2005), 81 % of children between ages 12 and 17 use the Internet regularly. Yerrick (2009) reported seventy five percent of teens use at least two digital devices regularly and spend about 6.5 hours a day with media. It is therefore inevitable to regulate or update our current teaching methods to educate future citizens. As Sabelli (1995) stated

We teach as we were taught. But what and how we learn have always depended on the tools available to students and teachers and should change with significant changes in the tools available. As the affordability of powerful microcomputers increases, educators become responsible for exploring the profound pedagogical implications of the changes brought about by technology on the practice of science. (p. 2)

Although there is widespread agreement that computer and information technologies should be an integral part of elementary and middle school science teaching (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996), there is a scarcity of research and data about the efficacy of using probes and computers to teach and learn science in elementary and middle schools (Zucker, Tinker, Staudt, Mansfield & Metcalf, 2008). Research studies exploring the possible use and benefits of probes and computers at the elementary level are particularly rare.

Educational Technologies have been developed to enhance the learning experience. Students do not learn only just by attending lectures. They need to actively participate in learning activities and construct their own meaning of the relationships between the scientific concepts and ideas. Some studies show that MBLs can be used to facilitate student learning of this complex relationships (Adams & Shrum 1990; Beichner 1990; Friedler, Nachmias, & Linn, 1990; Krajcik & Layman 1993; Laws 1997; Linn, Layman, & Nachmias, 1987; Millar 2005, as cited in Zucker et al., 2008).

Mokros and Tinker (1987) stated that in microcomputer-based laboratory (MBL) investigations the computer is interfaced with probes to measure physical phenomena such as temperature, light, force, pressure, or sound. The computer also includes a real-time data collection and graphing software. The success of microcomputer-based laboratories is attributed to several opportunities that it provides to learners. First, time is saved because of the computer's rapid performance and, as a result, elementary school students have the opportunity to devote that time to observation, reflection, and discussion (Rogers, 1995) that means more time to concentrate on scientific ideas. Second, MBLs help students experience real-time data collection. Students working like a scientist gather, analyze and interpret data. If this experience is provided to groups of students, their collaboration will be supported and strengthened as a result of the activity (Mandryk, Inkpen, Bilezikjian, Klemmer, & Landay, 2001). Third, MBLs reduce unnecessary drudgery of in the data collection process and so leave more time to devote to conceptual understanding. Finally, MBLs promote learners scientific understanding by

actually experiencing and doing the science, not just hearing about it (Trumper & Gelbman, 2002).

It is important to note that MBLs are potentially more beneficial when appropriately implemented with inquiry-based activities. One of the studies conducted at the elementary level showed that the combination of the MBLs and the inquiry-based curriculum appeared to be more effective than the traditional approach or even the combination of an inquiry-based curriculum with conventional laboratory procedures and apparatus (Nicolaou, Nicolaidou, Zacharia, & Constantinou, 2007). Several other studies also reached the same conclusion (Zucker, Tinker, Staudt, Mansfield, Metcalf, 2008; Avraamidou, Evagorou, Demetriou, & Vrasidas, 2008; Yerrick & Johnson, 2009; Gado, Ferguson, & van't Hooft, 2006). Considering the findings of these studies, I intended to inquire into the following research questions:

1. To what extent will an inquiry-based instruction supported with real-time graphing software improve fourth grade students' ability to interpret graphs as representations of physical science concepts such as temperature and motion?
2. To what extent will an inquiry-based-instruction supported with conventional laboratory equipment improve fourth grade students' ability to interpret graphs as representations of physical science concepts such as temperature and motion?
3. Are there any differences between real-time graphing software supported inquiry and conventional laboratory apparatus supported inquiry in terms of

improving fourth grade students' ability to interpret graphs as representations of physical science concepts such as motion and temperature?

## CHAPTER 2

### REVIEW OF THE LITERATURE

This literature review consists of 19 studies that have different focuses and purposes, but all related to exploring the impact of microcomputer-based laboratories (MBL) at elementary, middle and high school, and college level science education. The first part of the literature review includes seven studies exploring impact of MBL on students' understanding of scientific concepts. The second part is an examination of preservice and inservice teachers' belief, perspectives and decision changes related to MBL technology implementation in their current and future instructions. This section includes 3 studies. The third part focuses on how MBL can be designed and integrated into teaching and it has 5 studies. The fourth section reviews the impact of MBL on students' understanding of graph construction and interpretation. This section includes 4 studies.

#### **Microcomputer-based labs and students' understanding of scientific concepts**

This part of the literature review includes 7 studies. The following 7 studies examine the impact of probeware use on elementary, middle and high school students' understandings of scientific concepts in different contexts such as MBL effect on students' understanding of mechanics (Dimitriadis, Papatsimpa, Kampouris-Papamihalis, Karanikas, & Kalkanis, 2000), students' understanding of scientific phenomenon in high school (Marcum-Dietrich & Ford, 2002), feasibility and educational value of probeware (Metcalf & Tinker 2004), quantity and quality of technology use (Lei & Zhao 2007), inquiry-based lake investigation in elementary level (Avraamidou et al. 2008), specially-

designed inquiry-based TEEMSS curriculum in 3-8 grades (Zucker et al., 2008), and inserting laptops and science technology tools into middle school environments (Yerrick & Johnson, 2009).

Dimitriadis, Papatsimpa, Kampouris, Papamihalis, and Kalkanis (2000) conducted a series of seven experiments to understand the effect of MBL on Junior High School students' understanding of heat and mechanics. Five grammar schools in Athens, Greece were selected for the study. Each school had one experimental group and one control group. Classes in the control group had a stopwatch and a cart. On the other hand, the experimental group used various means and worked in an MBL environment that included a computer, a printer, necessary software, a projection screen, a video projector, and sensors of position and force. The teachers were the same for both classes in each school. The experiments included all of the basic topics of mechanics including linear motion, Newton's laws and conservation of momentum. The efficiency of each intervention was evaluated through a questionnaire that completed one week after every laboratory experiment.

The results of this study showed that students in the experimental group showed higher success in identifying trajectory motion from a motion diagram, not confusing position, velocity and acceleration diagrams and discerning the analogy of force-acceleration. Students were also able to comprehend Newton's third law and the conservation of momentum that is derived from it. Moreover, students in the MBL-based learning environment described the behavior of a natural system based on a model.

Marcum-Dietrich and Ford (2002) conducted a study to investigate the impact of computer probeware on students' understanding of the phenomenon particularly decomposition of hydrogen peroxide in the presence of the enzyme catalase, students' understanding of discourse science, and their ability to participate in the process of science. This study was conducted in Unionville High School, a public school in Unionville, PA. It is located in an upper-middle class, suburban, professional community with an enrollment of 1100 students where 92% pursue higher education and less than 1% qualifies for the reduced lunch program. This school is academically high achieving and achieved the third highest score on the state's standardized, academic achievement test. They had been using MBL for 3 years when this study was conducted. Researchers conducted the study in five 10<sup>th</sup> grade biology classes that ranged in size from 14 to 26 students.

To test students' understanding, they used a combination of pre and posttests, student designed laboratory procedures, lab reports, and student interviews. They assessed student ability to use the discourse of science and their proficiency in engaging in the process of science through videos that recorded students performing laboratory exercises and student interviews. Moreover, the researchers evaluated students' understanding of laboratory procedures through laboratory summary documents called Vee-diagrams. In this form of report, students reflected upon their experience in the laboratory in a single page, helping the researchers to measure students' overall understanding of the laboratory experience.

Students received three days of instruction about enzyme action in the classroom. Before the laboratory exercise, students took a pretest that assessed knowledge of the phenomenon. In the laboratory exercise, researchers randomly assigned half of the class as the experimental group that performed the laboratory using computer probeware and the other half used traditional methods. Every student, regardless of their group assignment, had to design and conduct an experiment to determine the effects of an environmental change such as pH, temperature, or presence of an inhibitor on the function of the enzyme.

While students performed the laboratory activities, researchers videotaped one group from each of the five classes. In total, they totally videotaped five laboratory groups and three were using the computer probeware and the other two groups used traditional laboratory apparatus. One week after the laboratory experience they interviewed six students, five from the computer probeware group and one from the traditional group. The videotape and interview transcripts were used to evaluate students' ability to participate in the discourse of science as well as their overall understanding of the phenomenon.

Two days after the laboratory exercise, students took a posttest that had the same questions as the pretest, but in a different order. They used the pre and posttest to determine students' gain in knowledge as a result of the laboratory experience. Understanding of the laboratory experience was assessed using the students' laboratory summaries in the form of Vee-diagrams. In these Vee-diagrams, students were questioned about the overall purpose of the laboratory, the questions investigated, the



data collected and the conclusions drawn. The researchers had students design a portion of the procedure, record their data, write a conclusion for their findings and answer series of questions related to the laboratory exercise.

When students' gain in learning quartiles examined, the results of this study indicated that students using computer probeware were able to make better connections with their experience in the laboratory to their general understanding of the phenomenon. They attributed this success to probeware's ability to instantaneously provide data as a graphical representation gathered in the laboratory.

The students' Vee-diagrams showed that using probeware scored higher than the students in the traditional group. Although this difference is not statistically significant, it is the highest difference they obtained from the three measurement tools (lab summary, lab report, and test gain). This means that students were able to understand the laboratory process better with the help of probeware. This gain was attributed to probeware's characteristics that is making the connection between the data and phenomena in a way that students would be able to make sense about it.

Laboratory video transcripts and interviews in this study indicated that students were still struggling to understand the language and discourse of science even though they were in the 10<sup>th</sup> grade. The researchers indicated that the students' lack of ability to understand the language and discourse of science explained the lack of significance in achievement differences.

Metcalf and Tinker (2004) conducted a study to investigate the feasibility and educational value of probeware and associated instructional materials in middle school

science education. To examine the feasibility, the study focused on costs, teacher professional development, and instructional design. This study was a part of Technology Enhanced Elementary and Middle School Science (TEEMSS). The goal in this project was to come up with two instructional units in which probeware can economically be implemented. This study also focuses on evaluating student learning outcomes from these two units which are motion and forces and transfer of energy if they are taught by a typical teacher who had limited in-service training. And by dividing teachers into two groups, it also aims to explore which method (face-to-face version or online workshop) could lead an effective implementation by typical teachers.

This study was conducted with three groups of teachers. Trial 1 composed of 19 teachers who were taught by face-to-face workshop. These teachers were from United States, Australia, and Israel. Trial 2 had 11 teachers around the United States who received teacher professional development online. The first two teacher groups conducted teaching in 2002. And Trial 3 was group 8 teachers that were sampled from these teachers for a brief follow-up study that is conducted in 2003.

For this project, the researchers developed 2 middle school science curriculum units, 6 low-cost probes that interface between handheld Palm computers, and CCLabBook software. The primary teaching strategy in this study was inquiry-based guided science explorations.

Pre and posttests, surveys and interviews, and classroom observations are the data sources in the study. To achieve the goals this study, they developed forces and motion and transfer of energy units that last 10 weeks. Trial 1 teachers used the materials for

average of 20 days over 2 months at the end of the school year, and covering on average about half of the Motions and Forces unit and about one quarter of Transfer of Energy unit. Trial 2 teachers used the materials for 9 days over 2 weeks at the end of the school year, and Trial 3 teachers, used the materials for 2–3 weeks and covered about 20% of one unit. For Trial 1, the data shows that both Australian classes showed significant improvement: 12% on the MF (Motion and Forces) test with teacher Q, and 18% on the TE (Transfer of Energy) test with teacher O. The two other TE test scores showed significant improvement as well: 12% and 15%. The other teachers' classes showed little to no difference between the students' scores on the MF test. For Trial 2, there was only one MF data set available, and those students showed a small 5% improvement. For Trial 3, there were 6 data sets, and all showed improvement, 15% and 6% on the MF test, and 3% to 17% on the TE test.

Some interpretations can be made from the data. Firstly, students' high pretests scores (averaging 50%) decreased the usefulness of the test as an assessment tool. Secondly, both Australian teachers' greatest achievement is explained with the extra time they spend on with their students using TEEMSS materials. This suggests that students can learn the content using TEEMSS curriculum when given sufficient time to do so. Thirdly, Trial 1 test scores on Motions and Forces appeared to be adversely affected by the instructions. And lastly, students' ability to interpret position-time graphs and temperature time graphs has shown to be improved by using the TEEMSS curriculum.

The data from pre/posttests showed that students had significant improvements that are up to %19 difference between the pre/posttests. The highest improvement was

observed in the Australian classrooms (Trial 1) where students had more interaction time with TEEMSS materials. In the post-interviews and surveys, Trial 3 teacher reported that students learned significantly higher from the use of TEEMSS materials and students themselves explained that they “learned the science” better from the TEEMSS activities than other activities they have done in science class. About TEEMSS material’s feasibility, the data showed that either face-to-face or online, teachers were able to implement the units quite well. This statement supported by the data from post-interviews and classroom observations in which teachers and students were able manage almost every investigations.

Lei and Zhao (2007) conducted a study in a middle school to examine how the quantity and quality of technology use affect student learning. It aims to understand how technologies are used by students, what technology uses are popular among students and what technology uses are effective in increasing students` academic achievement. “Technology use” is also defined so that any misunderstanding to be prevented. It (technology use) means in this study that it is the application of a technology function to solve practical problems.

The participants of this study are students and teachers from a middle school in the state of Ohio located in a middle- and upper-class neighborhood. This school has total 237 students and every classroom have a computer projector, overhead projector, TV, VCR, and internet access. Each student also has a laptop.

Data collected in 2003-2004 academic year comprises surveys and interviews. Pretests were administered in 2002-2003 academic year. On the other hand, posttests

were administered at the end of the academic year and they had all sections in the pretest survey and one additional part that questioned students' technology use. The data gathered from interviews targets to understand rate of participants' particular technology uses such as overhead projector and computer related technologies. At the end of these surveys, total 130 students' data were kept for analysis. Data from interviews were collected twice over the year from 10 teachers and 9 students to understand what technology they use and how they use them.

The results of this study suggest that the amount of time students spend on using computer is inversely proportional to student's academic achievement (GPA) when it exceeds 3 hours. In general, it proposes that spending too much time on computer use may limit the time that is spared for learning activities. Hence, it could decrease students' academic achievement. Secondly, quantity of technology use is less significant than quality of technology use. The purpose of its use is going to determine whether or not students will benefit from using computers. Lastly, most frequently used technologies may not have positive impact on student achievement. On contrary least frequently used technologies may have positive impact on student achievement. The least frequently used technologies are Science Probes and Aleks and this study shows that students using these technologies had the most increase in GPA.

Zucker, Tinker, Staudt, Mansfield, and Metcalf (2008) conducted a study to find achievement differences of 3-8 grades students who were taught by teachers not using TEEMSS units and next academic-year-students who were taught by the same teachers using inquiry-based TEEMSS units with probeware and computers. The researchers

conducted this study with 66 teachers, who are located in various school districts in three states, used more TEEMSS units during 2004-2005, 2005-2006 and 2006-2007 academic years. However, this paper focused on reporting achievement differences of students with same teachers who did not use TEEMSS unit in 2004-2005 and used TEEMSS units in 2005-2006 academic year.

In 2004-2005 academic year, some teachers (number is not specified) used the TEEMSS materials to teach eight units while other teacher did not use the TEEMSS materials. In 2005-2006 academic year, all participating teachers used the TEEMSS materials. That was where the data came from. The teachers were same, so one potential threat to the validity of findings was eliminated.

TEEMSS units were designed in a way that they are applicable to any computer or probeware the school chose to use. The TEEMSS learning strategy was based on student investigations of real phenomena using probes. The researchers also produced software, curriculum materials, and an online course to prepare teachers. For this project, they developed 15 units and each unit contained two 1-week investigations. These units had common steps like discovery question, several trials, analysis, and further investigations. In the teacher version, each unit had background material, answer to questions and a discussion guide.

Items on the TEEMSS tests were primarily drawn from 12 existing standardized tests, NAEP, and TIMSS, and regional and state tests that were similar to their item construction. SRI international prepared 1500 items, but 380 were identified as sufficiently aligned by Concord Consortium staff. Tests were operated in November 2004

and some students were asked to “think aloud” in order to test student understanding of questions. Eventually, 60-100 students completed each test. The validity testing was used for several reasons. They were used to select proper questions for grade levels, to evaluate inter-rater reliability for scoring, and to compare pre/post variation of questions.

Scorers, SRI international staff, did not know whether pre- or post- tests they were evaluating. Teachers took written surveys both before and after they participated in the project. After teaching a TEEMSS unit, the teacher provided their experiences by completing a special survey (signposts).

There were statistically significant differences in student achievement across four units between students who learned through TEEMSS materials and students who did not learn through TEEMSS materials. The four units were sound (grades 3–4), electricity (grades 3–4), temperature (grades 5–6), and motion (grades 7–8). The effect sizes for the four units with statistically significant differences are 0.58 (sound), 0.94 (electricity), 1.54 (temperature), and 0.49 (motion). There were no statistically significant differences between the two groups across other four units. These four units were sensing (grades 3–4); levers and machines, and monitoring a living plant (grades 5–6); and pressure (grades 7–8). Moreover, students used TEEMSS materials developed better understanding of graphs than those who did not use TEEMSS. On the other hand, it had no or little benefit on recall of science-related facts.

The results of this study indicated that using computers and probes in elementary and middle school classrooms can result in substantial learning gains. For certain curriculum units, use of computers and probes results in larger learning gains than

instruction on the same topics without computers and probes. There needs to be further research in other subjects in science as well.

Avraamidou, Evagorou, Demetriou, and Vrasidas (2008) conducted a qualitative case study to inquire the use of handheld technologies to support inquiry-based learning in elementary science classrooms. In this study, students were taken to test the water quality of a lake with the use of handhelds after discussions in the classroom environment. With the help of a scientist and a teacher, 5 students were actively collecting and analyzing data gathered from a lake which had water quality problem.

Participants attended 4 hours per week and 10 -11 weeks long study. Data sources were videotapes recorded in and out of the classroom, interviews with students and the teacher after the instruction. The result of this study indicated that the handhelds appeared to be supportive of the task of the outdoor environmental study, particularly because of the fact that the students were able to concurrently gather, report, and organize the data collected at the site. Students showed great enthusiasm and increased motivation to the activities which were designed in accordance to inquiry-based curriculum.

Yerrick and Johnson (2009) conducted a study about the effects of inserting laptops and science technology tools into middle school environments while providing responsive professional development for middle school science teachers in classrooms. They also sought to find answers to these research questions; what the impact on students' learning and science knowledge is when teachers employ inquiry pedagogies with technological tools, how students perceive themselves as learners and their teachers' efforts with technology to improve science teaching, and which educational technology



students perceive as helpful in learning science. They focused on two main purposes: insertion of actual data to complement instruction and laboratory investigation and the use of media creation tools to give the students the opportunities to co-construct knowledge of abstract concepts.

This study was conducted in 2007-2008 academic year. It was done in one suburban middle school in New York. They selected this middle school, because teachers within the school had relatively little access to classroom technology. Two of the ten science teachers accepted to be fully participant of training, planning, implementation of the technology tools and new teaching strategies. Each of participating teachers was given a notebook. These teachers (one physical science teacher and earth science teacher) used their notebook and technological devices, aligned with the prepared curriculum, to implement inquiry-based teaching strategies in their classroom.

Local New York University prepared curricula and evaluation measures that were tested with the summer school students. This curriculum was consistent with technology education reform visions.

All of the students enrolling in science courses were invited to participate in a survey regarding their use of technology at home and at school. More than 500 students from all 10 science teachers' classroom responded to this survey. This survey helped them compare the observed teachers and the other 8 teachers' students' learning styles, observed teachers' strategies, use of technology, and achievement data. They also conducted interviews, focus groups and gathered field notes so that they would understand how technology was employed in the project teachers' classroom.

As a result of this study, Yerrick and Johnson (2009) concluded that teachers remaining in the project for the duration of the year noted that students were not only more engaged and more motivated, but also better able to assimilate what teachers taught because of the way each learned best. Teachers reported increased student enjoyment of the tasks of learning science. Teachers also mentioned that they spend less time covering content and still enjoyed the success of high achievement of their students.

Earth science enrollment increased more than 42% for the year that study made. This was evident when policy changes opening up earth science to any student still resulted in 100% student success when supplemented by technology and inquiry strategies. It may very well be that more students may actually be able to achieve the highest level of science performance if appropriate technology and revised pedagogy replaces a traditional repertoire.

Students reported through surveys and interviews that teachers' new strategies actually connected better with their needs. Students found their teachers to be more effective and teachers not only found themselves more energetic, but also they realized that their scores improved when compared to previous years.

**Summary.** The 4 studies (Zucker et al., 2008; Avraamidou et al. 2008; Yerrick & Johnson, 2009) above come to the same conclusion that probeware use in inquiry-based learning environments positively affects students' learning gains. With the integration of probeware, the inquiry-based learning environment in science teaching was shown to be more beneficial more to students' understanding in sound, electricity, temperature and motion of 3-8 graders (Zucker et al., 2008), force and motion and energy transformation

of middle school students (Metcalf & Tinker 2004), metric system, matter, atoms, heat, force and motion, wave motion of middle school students (Yerrick & Johnson, 2009), water quality of 6<sup>th</sup> graders (Avraamidou et al., 2008). Students also had significant increase in learning gains concerning Newton's 3<sup>rd</sup> law and conservation of momentum of high school physics students (Dimitriadis et al., 2000) and scientific phenomenon of 10<sup>th</sup> grade biology students (Marcus-Dietrich & Ford, 2002) although probeware integration was not conducted in the inquiry-based teaching environment. Additionally, students showed more interest and higher motivation in the process of implementation of probeware in the studies such as (Yerrick & Johnson, 2009) and (Avraamidou et al., 2008). Moreover, Yerrick and Johnson (2009) reported that less time is needed to cover science content with the aid of probeware.

### **Teachers' beliefs and perspective with regard to microcomputer-based laboratories**

This part of the literature review includes 3 studies. These studies examine the preservice and inservice teachers' belief, perspectives, and decision changes related to MBL technology implementation in their current and future instructions.

Gado, Ferguson and van't Hooft (2006) conducted a study to investigate what conditions and factors affect preservice teachers' decision to use handheld computers in scientific investigations and also explored aspects of student learning and classroom practices that would be affected by handheld-based science activities.

Participants of this study consisted of 17 undergraduate and 4 graduate students, total 21 preservice teachers that were registered for an undergraduate science method course. Researchers divided preservice teachers into groups of 4-5. To create a ubiquitous

computing environment, which was defined as students provided with different types of technologies, the HBL (Handheld-based Laboratories) used in this study consisted of five handheld computers. For this reason, each group was given only one handheld computer and also wireless laptops to have an access to relevant science background content knowledge and experiments through Internet. Additionally, they were supplemented with the Science Explorations with Palm Handhelds activity book, probeware, and DataStudio Software. Preservice teachers experienced 15 handheld experiments in this study.

Researcher's instructional framework influenced by the "tool application" strategy developed by Adams, Krockover and Lehman (1996) for using computers in science education. Along with instructional framework preservice teachers went through three phases in the process. In the induction phase, they explored handheld computers and probes and viewed a CD ROM entitled *Palm Education Pioneers: Examining the Potential of the Handheld Computer*, and discussed the influence of the CD ROM on their science teaching approaches and what integrating science and handheld tech could offer to students. The concept development phase, preservice teachers were familiarized with the process of scientific inquiry. The last phase, concept application phase, engaged preservice teachers in problem-based and student-initiated inquiry. They designed their own investigations and handheld-projects appropriate for elementary and middle school students. They also designed lesson plans, engaged in reflective and constructive analysis of their experiences and possibility of using handhelds in science instruction.

Data for this study were collected through interviews, student reflection papers, journals, and classroom observations of peer teaching. Prior to HBL implementation participants were interviewed.

During the implementation students attitudes toward using handheld computers for science activities were assessed through interviews, classroom discussion, and instructor field notes. Other than interviews, students were also asked to write a reflection paper on their abilities and understandings of the use of handheld technology in the science classroom. Researchers applied Attitude Toward Handheld Computer Scale (ATHCS) to test participants' attitudes toward integrating handheld computers in science activities in primary school.

Both qualitative and quantitative data were collected and analyzed in this study. The results of this study indicated that handheld technology-based inquiry activities into Science Methods courses can have substantial impact on preservice teachers' attitudes, self-efficacy, and conceptual understanding related to integrating technology in their future classes. It also suggested that HBL can motivate students and improve their understanding of science concepts. As resulted from several studies of Microcomputer-based Laboratories (MBL) and Calculator-based Laboratories (CBL), Handheld-based Laboratories (HBL) were also found to be "reducing the time needed for tedious data acquisition and organization, thereby allowing more time to be devoted to experimental design and interpretation" (Adams et al., 1996, p. 68). Moreover, because of its portability, handheld devices allow teachers to develop inquiry-based activities that can be carried out in real-life situations.

Data acquired from preservice teachers suggested that under the right conditions preservice teacher can become aware of the advantages of integrating technology and this benefits their students in the future. If they are not trained to use handheld technology, they will not use it. Another implication from the study is that curriculum is needed to be designed in a way that supports the use of handheld computers.

Lyublinskaya and Zhou (2008) conducted a study about graphing calculators and data collection technology in undergraduate science methods course for preservice elementary school teachers. The researchers focused on this issue to get an answer to whether preservice teachers' knowledge and comfort with the use of graphing calculator technology and the preservice teachers' perspectives of using this technology were influenced by the integration of this technology into the methods course.

The participants of this study consist of 25 day session and 13 evening session college students. The comparison of the day session and the evening session showed that day session students were younger, had less college education, and less prior experience with graphing calculator because of less calculator ownership at home.

The study took place at public college in New York City. The researchers integrated some graphing calculators and probes into the two sessions of the science methods course for elementary school teachers during the spring semester of 2006. The day session spent five weeks on learning theories and 10 weeks at schools for teaching practice. Students undertook two projects that targeted to teach them how to use graphing calculator technology. They not only learned how to use this technology but also they learned how to apply it in a classroom environment. The evening session met 14 times

during the semester for three hours weekly. In addition to the two projects used in the day session, seven more calculator-based activities are developed and integrated into the class.

The researchers gathered data through quantitative and qualitative measurements. They applied a pre- and post-survey to assess preservice teachers' attitudes (confidence level, importance, and interest) toward calculator-based technology. The pre-survey was administered at the beginning of the semester and the post-survey was administered at the end of the semester to all preservice teachers in both sections. In addition, preservice teachers were asked to complete several open-ended reflections throughout the semester that served as qualitative data.

The results of this study showed that this course appeared to improve preservice teachers' confidence although it was not significant. And preservice teachers' perspectives and attitudes toward calculator technology did not significantly improve as well. The preservice teachers' interest and their feeling of calculator based technology's importance did not have a significant change by the end of the course. However, it is interesting to note that preservice teachers tended to view calculator technology more as a teaching tool than a tool for their own productivity. Although teacher candidates' confidence with the use of probes was improved (not significant), more participants felt less confident to use calculators in teaching and learning at the end of the course. The researchers explained this data with preservice teachers' realization of complexity of using graphing calculators. Another conclusion can be drawn from when we take a look at the experience difference between the teachers is that more experience and practice

provides preservice teachers with better understanding of the benefits of this type of technology for their future students and for their own learning.

One limitation of this study was that the study was conducted in a science methods course, not in a science course. That is why the preservice teachers perceived graphing calculator as tools for teaching for students, but not as tools for their own learning. Another important conclusion can be drawn is that even if pre-service teachers perceived technology as useful, this doesn't mean they are confident enough to use it. The researcher concluded that the integration of calculator-based technology into methods courses can change preservice teachers' perspectives on the use of technology in teaching and learning, but it is not enough to improve their confidence in using it.

Smith and Heaton (2005) implemented a program to increase student achievement and prepare highly qualified teachers. This program was aligned with state and national standards in science and technology of its particular year.

Participants of this study were fifteen elementary and secondary teachers in West Virginia. An average of 33.4% of students scored in the lower two quartiles in science as reported in the SAT-9 for the 2002-2003 school year and West Virginia Policy 2520 Content Standards and Objectives states that students will engage in active inquiries, investigations and hands-on activities for minimum of 50% of the instructional time to develop conceptual understanding and research/laboratory skills. These two reasons actually motivated the researchers to plan a program that make emphasis on science.

The program consisted of a one week summer workshop and additional follow-up activities related to the week. As reported by Smith and Heaton (2005), the focus of the



activities was the use of handheld computers to enhance the delivery of science education to students. Smith and Heaton (2005) explained briefly this process as;

Throughout the week the teachers were provided hands-on experiences with handheld computers, freeware applications, and probeware. Instruction was provided through simulated teaching and learning. These hands-on inquiry-based experiences consisted of learning centers in which the participants observed, experimented and practiced using the technologies. It was essential for teachers to learn each of the technologies, because they not only received the training to integrate science and technology, but also the resources to implement the activities in their own classrooms. (p.2)

The researchers provided each participant with the Palm Zire 72, which included a digital camera, external probes for data collection, various freeware programs, Presenter to Go, Britannica SD card, and several activities and lesson plans for instruction. They also received Intel Play QX3 computer microscope and appropriate training and materials to integrate the microscope in the classroom. The program was also focused on lesson planning for the upcoming school year. In the discussion time, each participant elaborated on their plans to use the technologies and completed lesson plans using several technologies were required at the end of the weeklong workshop.

For the support and evaluation purposes, fall site visits were conducted by the presenters after the summer workshop was completed. Upon completion of the summer workshop a follow-up class meeting was held to discuss implementation of the

technologies along with successes and failures. And participants completed additional surveys in this meeting.

The results of this study showed that the amount of time and access to proper training for teachers to use technology to support learning plays a major role in determining whether or not technology has a positive impact on achievement. The appropriate training for implementation with the new technologies was the key for teachers to feel competent to integrate technologies in their classrooms.

**Summary.** All 3 studies (Gado et al., 2006; Lyublinskaya & Zhou, 2008; Smith, & Heaton, 2005) reached the same conclusion that preservice and inservice teachers are needed to be trained in a way that they will understand the benefits and promises of the integration of MBL and as a result they feel competent enough to implement them in their teaching. In addition, Lyublinskaya and Zhou (2008) study showed that even if teachers accept the benefits of MBL, it may not affect their confidence in implementing MBL in their classrooms. Suggestion made by Gado et al. (2006) is particularly important. They stated that pedagogical practices aiming to infuse inquiry-based activities into science methods course would have substantial effect on teachers' decision for future implementation. Gado et al. (2006) also suggested that MBL reduces the time needed for data acquisition and organization by allowing more time for experimental design and interpretation.

### **Design and integration of microcomputer-based labs**

This part of the literature review includes 5 studies. The following 5 studies examine how MBL should be designed and integrated into teaching. For this reason,

Bernard (2001) investigated MBL as a technology versus cognitive tool and Parr et al. (2001) designed a curriculum with BIODIDS Sequence software. On the other hand, Mandryk et al., (2001) tried to tackle two obstacle of handheld devices, Inkpen (1999) investigated what kind of handheld students` wanted and Royuk and Brooks (2003) compared learning gains of MBL used cookbook lab group students and active-learning MBL physics exercise group students.

Bernard (2001) investigated the learning affects of using microcomputer-based laboratories (MBL) as a technological tool and as a cognitive tool. The data was collected from introductory university level physics (mechanics) courses (25 – 40 students) at Swedish University. All three cases were treated with MBL-labs, but in Case I laboratories were in active engagement mode using a POE-cycle (predict-observe-explain cycle) in a course for engineering students. In Cases II and III the MBL-labs were implemented as “formula verification labs” for preservice teachers. The only difference between the Case II and Case III was that the collision lab from Case II was changed into POE and active engagement mode. Basically, in Case I MBL were used as technological and cognitive tool whereas in Case II and Case III MBL were mainly used as technological tool (measurement, processing and display of experimental data).

In this study the conceptual tests Force Concept Inventory (FCI, Hestenes et al., 1992) and Force and Motion Conceptual Evaluation (FMCE) developed by Thornton and Sokoloff (1998) were used as a pretest and the posttest.

The results of this study showed that MBL as a technological and a cognitive tool had higher learning results when compared to MBL as a technological tool. And the

change from a formula verification approach to active engagement approach as in the case of Case II and Case III also increased the students' learning. Other studies (Bernhard 2000; Hamne & Bernhard 2000) showed that the observed difference cannot be attributed to students' different backgrounds in this case engineering students versus preservice teachers. The results of this study indicated that MBL-technology, and other forms of computer aided learning, cannot be implemented as only a technology. Bernard (2001) concluded that both cognitive and technological aspects should be equally emphasized to improve student learning when using computer-assisted learning.

Parr, Jones, and Songer (2004) conducted a study to investigate the use of BioKIDS Sequence together with PDA (Personal Digital Assistant) on students' scientific reasoning. Researchers developed interface design specific for target audiences and purposes. Icons were used instead of text entry to make it efficient for students. In addition, navigation of screens was largely linear and represented taxonomic common sense. Taxonomic common sense was defined as adhering to accepted animal classification at the top level to reinforce content.

Their study was composed of three parts. In part 1, they collected and analyzed CyberTracker data logs from eight classes of primarily urban 6<sup>th</sup> graders (n=163 students). In part 2, they administered student opinion surveys (n=45) and conducted one-on-one interviews (n=6) at the end of the 8-week biodiversity unit. In part 3, they collected and analyzed CyberTracker data logs from a technology practicum exam administered to students both before (n= 346) and after (n=198) the biodiversity unit.

In the first part of this study, researchers had students take the practice activity in which students entered data using the BioKIDS Sequence for four unlabeled photos of animals. After the practice activity, students collected 278 field-based observations. In the second part of the study, researchers administered a questionnaire with nine Likert-format questions and three open ended questions to 45 students to evaluate their beliefs about the BioKIDS Sequence. After the survey six students were asked to expand on their return survey responses during one-on-one interviews. In the part three, to measure usability and accuracy rates of the BioKIDS sequence, researchers assessed students' performance on a technology practicum exam. The pretest was administered before the BioKIDS curricular unit. And after completing the 8-week BioKIDS curricular unit, students took the posttest.

According to the data gathered from this study, researchers concluded that most students were able to learn to use the BioKIDS sequence as an appropriate tool and technique to gather, analyze, and interpret data (National Research Council, 1996). This means the BioKIDS Sequence and the PDA (personal digital assistant) technology were used as a meaningful tool to support scientific reasoning.

Almost 30% of students who had no experience of using PDA could record a sighting for the first time. This result suggests that the BioKIDS Sequence is quite usable for students in the fifth and sixth grade. The researchers' results also concluded that the three design principles contributed to the usability of the BioKIDS Sequence. They were Use of Icons, Linear Navigation, and Taxonomic Common Sense features of the design.

The BioKIDS sequence was found to be effectively assisting students in accurate data collection. First, it allows students to skip the step of transferring data from paper to computer, a process known to be error-prone in adults. Second, the BioKIDS Sequence design provides reminders of what students should look for in making accurate observations. Third, the BioKIDS Sequence provides easy ways for students to flag vague or questionable data that they collected.

Mandryk, Inkpen, Bilezikjian and Klemmer (2001) conducted a study to tackle two obstacles in the nature of handheld devices. Since they are designed to be a personal device, students might be deprived of the benefits of collaborative learning. And the small size of the screen limits the information that is displayed. Therefore, they came up with connection of multiple devices to form a larger surface displaying more info than any individual handheld.

The researchers used a Palm-based game that assists children in exploring genetics concepts. Students were supposed to produce a fish with a particular set of characteristics by simply mating other students' fish through the handhelds' infrared port. This game can only be played as a group to achieve desired goals. Observations of children playing Geney showed that they had difficulty in deciding which fish to mate. Students were provided about the information of the traits of each fish and their family trees. However, students needed more info about dominant and recessive genes. To bring this complexity to students' level and scaffold students' decision-making, the researchers conducted participatory design sessions in which they observed the students while playing Geney. The researchers came up with a feature called WHAT-IF in which

students were provided with genetic possibilities for a number of pairing of fish. The WHAT-IF feature provided information to children so that they can use together to make decisions in Geney. To use this feature, students formed a group in which one student became the *manager*; the others were *participants*. The *manager* chooses one fish in his or her pond and each *participant* chooses one opposite sex fish. With the help of beaming technology, they shared and saw the traits of the potential offspring from mating that fish with the manager`s.

To gain insights into children`s use of WHAT-IF, the researchers conducted an exploratory study with five girls and two boys between the ages of 12 and 14. In the first session students were introduced to the Palm handhelds. Then the researchers gave the children an introduction to Geney and allowed them to play for 20 minutes to get them acquainted with the game. In the second session the following week, the researchers gave the same children an introduction to WHAT-IF and an hour to play with it. Then, students filled out a post-session questionnaire.

The results of this study showed that students were excited by sharing information across handheld computers and were motivated to interact in this environment. The combined use of multiple interconnected devices to form a larger, shared workspace can be an effective collaboration technique.

Inkpen (1999) conducted a study to have students design personal handheld devices for their learning. He wanted to learn childrens` ideas about how they would want handheld devices to be in learning environment. Students actively engaged in the design of handheld technologies in two aspects: mobility and shareability.

The participants of this study were composed of thirty-eight 10-12 year old children from six classes in public elementary school on the east side of Vancouver BC. The neighborhood is in a lower-economic area of Vancouver. Students were from diverse ethnic backgrounds, %74 of students reported having a computer at home and %76 using a computer at least few times a week and %53 using a computer almost every day.

To collect the data, the researcher used three research activities: background questionnaire, participatory design sessions, and paper-based notebooks. In the background questionnaire, students were asked the amount of time the children spend using computers or playing electronic games; whether or not they have computers or video game players at home; and where the computers are located in the home. Preference data was gathered on where children would like to be able to use computers and what type of activities they would like to be able to perform. Children were also asked to indicate whether they preferred playing with a partner or playing alone when they used computers or video games.

In the participatory design sessions, students were asked to create low-tech prototypes representing what handheld computer technology would look like and what functionality it would have. This research methodology was pioneered by Duruin and Solomon (1996). The children used various arts and crafts supplies such as paper, pens, pencils, markers, colored pencils, tape, glue, scissors, post-it notes, and plastic icons to construct their prototypes. Children were also given a physical platform on which they illustrated their preferred size for a handheld computer. The children worked in groups of two to four for a one and a half hour period in which they were videotaped.



Paper-based notebooks were used to learn of “where” children would like to use handheld computers. In this activity students were given a small coil notebook and were asked to imagine that it was a handheld computer. The children were required to carry the notebook around with them for three days and write down places that they would like to use their handheld computer. They were also asked to note list of activities supported by their handheld computer. Throughout the process, students were videotaped and observations and ongoing informal discussions were gathered through weekly visits to the school.

The result of this study can be summarized under two focus sections: mobility and shareability. Results from all three activities related to mobility of handheld devices revealed that children wanted to be able to access computer technology in variety of places (over thirty distinct places). Small and portable computers are necessary in this type of integration. Most of the children in the participatory design activity constructed relatively small handheld computers that could be folded to make the unit more compact for portability. Throughout the three research activities, shareability was implicitly supported by children's desire to use the technology with friends and use it for activities that are often performed with other people. However, the children`s prototype designs did not explicitly contain necessary functionality to support shareability. This might be because of the common notion about ‘personal’ technologies which might be interpreted as used by single person.

Future research on how to facilitate learning with handheld computers and how to integrate this technology into the school environments is essential to come up with more

specific effective integration aspects. But this study helped to provide students` perspective on the use and design of handheld technologies in a learning environment.

Royuk and Brooks (2003) conducted a study to compare learning gains of MBL used cookbook lab group students and active-learning MBL physics exercise group students. They also measured and compared students` satisfaction and perceived effectiveness between the two groups.

For this reason, Royuk and Brooks (2003) collected data from a trigonometry-based introductory physics course at a small private liberal arts college by dividing them into two lab sections. One of the sections participated in MBL mechanics exercises that were highly engaging and the other one completed labs written in a cookbook style that covered the same conceptual material and used the same equipment for the same amount of time. The group with engaging procedures called the interactive-engagement (IE) group which completed nine chapters of the lab manual *RealTime Physics: Mechanics* that also covered by the cookbook lab group. These chapters were introduction to motion, changing motion, force and motion, combining forces, force, mass, and acceleration, gravitational forces, passive forces and Newton`s laws, Newton`s third law and conservation of momentum, and two-dimensional motion. Both groups attended the same lectures and completed the same homework assignments and exams.

For the assessment purposes, the researchers used a pre- and post-instruction application of the Force Concept Inventory (FCI). The instrument was consisting of 30 multiple-choice questions and it was designed to measure students` conceptual mastery of Newtonian mechanics. In order to measure students` satisfaction and perceived

effectiveness, Royuk and Brooks (2003) developed and administered 13-item Likert-style survey which also included three free response questions.

The results of this study indicated that although it was not statistically significant, students completed the more engaging labs achieved higher normalized gains on a pretest-posttest FCI exam. And opinion data seemed to suggest that the cookbook labs were somewhat more popular with the students than the interactive engagement labs. The researchers as a result made a suggestion that the laboratory activities should engage students in making choices based upon physical principles and receiving feedback about those choices. They concluded that it is not just the gadgets, it is how you use them that counts.

**Summary.** The 3 studies (Royuk & Brooks, 2003; Mandryk et al., 2001; Bernard, 2001) reviewed above come to the same conclusion that students showed higher engagement and excitement while learning in MBL environment. The results from these studies implies that to get higher student learning gains, MBL are needed to be used both as technological and cognitive tool (Bernard, 2001), in a collaborative learning environment (Mandryk, 2001). When students were asked to state their own preference of handheld device, they chose and drew small and portable that is accessible almost everywhere (Inkpen, 1999). Students were able to understand and use scientific reasoning with BLOKIDS Sequence and PDA (Personal Digital Assistant) in a particular study (Parr et al. 2004).

## **Graph reading and interpretation**

This part of the literature review includes 4 studies. The following 4 studies examine the impact of MBL on students' understanding of graph construction and interpretation of 4<sup>th</sup> graders' temperature and time (Nicolaou et al., 2007), high school students' distance and velocity (Brasell, 1987), middle school students' light and time (Mokros & Tinker, 1987), and tenth grade biology students' construct and interpret line graphs (Adams & Shrum, 1990).

Nicolaou, Nicolaidou, Zacharia, and Constantinou (2007) conducted a study to investigate whether the use of Microcomputer-Based Labs, implemented within an inquiry-based activity, contributes to the development of 4<sup>th</sup> grade students' conceptual understanding of melting and freezing and ability to construct and interpret graphs of temperature and time.

For this reason, researchers chose the sample of 65 fourth grade students of 3 classes from randomly selected two schools. One of the classes, which consisted of 23 students, was randomly selected as the experimental group (EG). The EG was treated with Microcomputer-based laboratory and Inquiry-based curriculum. This Inquiry-based curriculum was constructed and aligned with the idea that the process of science cannot be learned by reading, listening or memorizing. It asserts that effective learning requires active mental engagement and so students need to be active learners. The teacher in this process has a role of a knowledge facilitator who scaffolds and guides the learning process through careful questioning rather than direct explanations. This inquiry-based curriculum was organized into four eighty-minute lessons and the experimental group

was divided into 7 mixed-ability groups, each provided with a portable computer and a data logging system. The other two classes served as control groups. The control group 1 (n=20) was treated with traditional laboratory apparatus and traditional national science curriculum. The national science curriculum was strictly following the corresponding lesson plans provided in the Natural Science Curriculum of the Cyprus Ministry of Education and Culture. And the control group 2 (n=22) followed the same curriculum as EG; however, the participants of this group did not have access to MBLs.

Data for this study was collected through pretest and posttest that were administered before and after the research intervention respectively. There were two science educators and three physicists to evaluate pre- and post-tests.

The results of this study show that inquiry-based curriculum supported with Microcomputer-Based Laboratories (MBLs) significantly increased elementary students' conceptual understanding of melting and freezing and ability of constructing and interpreting graphs. This study also supports the idea that, through carefully designed activity sequence, MBLs can lead to significant improvements in both conceptual understanding and graphing ability at relatively young ages (9-10 years old students). Moreover, it shows that the integration of MBLs and inquiry-based curriculum is more effective on students' understanding of melting and freezing and ability to construct and evaluate graphs than the traditional approach or even the combination of an inquiry-based curriculum with conventional laboratory procedures and apparatus. The authors believe that the success of MBLs results from its time saving capability in data gathering and

evaluating process. They think that this time after all can be devoted to focus more on observation, reflection and discussion.

They also came up with multiple explanations of the success of EG curriculum. Firstly, it allows students to experience the phenomena directly. Secondly, the sequence that concepts were developed is important especially in supporting the evolution of real meaning. For instance, they taught students the heat and temperature concepts separately before the melting and freezing subject matter. Thirdly, they devoted enough care and time to let students develop the conceptual understanding and this in return let them structure a higher sense of understanding. Finally, MBL helped them show students that data logging is not the end-process. Students were able to learn from the experience of MBLs as tools in investigating the phenomena, as a format for improving their understanding and as a medium for probing physical quantities.

Brasell (1987) conducted a study showing that extended experience with a motion Microcomputer-based Laboratory unit was adequate to improve high school physics students' comprehension of distance and velocity graphs when compared to traditional graphing method, a pencil-and-paper graph construction.

The participants of the study were all students (93 students) attending physics classes in seven rural schools in North Florida. Students were mostly seniors and they had been taught a unit on kinematics earlier in the academic year. The researcher formed four treatment groups; the Standard-MBL groups, the Delayed-MBL Groups, the Control Groups, and the Test Only Groups.

There were one main difference between Standard-MBL groups and the Delayed-MBL groups. That is; the Standard-MBL groups had an MBL motion unit that displayed data immediately after it was collected. In the Delayed-MBL Groups, the data was displayed after about 20 seconds it was collected. This was only difference between these two treatment groups. They both followed the same worksheets. The Control-Groups performed pencil-and-paper activities that paralleled the prediction and reproduction activities of the MBL treatments. They were asked to complete some distance and velocity activities. The Test Only groups did not participate in any motion graphing activities.

For each class treatments followed the same format, the experiment took three days. One day each for orientation and the pretest, treatment, posttests and debriefing. Data collection period extended over five weeks.

To evaluate the differences among the groups, the researcher collected achievement differences of groups in SAT, pretest and posttest. The pretest was developed by Thornton (1986) and the posttest was conceptually the same, but the difference in format affected students' performances. Therefore, he could not use the difference as a measure of change in performance.

The results of this study showed that students in the Standard-MBL groups made significantly less graph errors and achieved significantly higher in kinematics concepts than students in the Delayed-MBL groups. The results of this study also showed that students in the Delayed-MBL groups were less motivated and engaged, more concerned with procedural issues than conceptual issues when compared to real-time MBL groups.

Mokros and Tinker (1987) conducted a series of studies to understand MBL's impact on middle grade students' ability to interpret graphs. Before undertaking the experimental study, they conducted a descriptive investigation as in-depth-examination of middle school children's graphing skills and misconceptions and then an intensive observational study was administered in order to evaluate the ways in which students learn graphing skills through MBL.

In the descriptive part of the study, clinical interviews were conducted with 25 seventh and eighth grade students to better understand children's graphing skills. These students were selected according to availability and self-nomination. The interviews consisted of six graphing items that students were asked to read the problem loud and to "think loud" while solving the problem. And the interviewer made counter suggestions to test the strength of their arguments. After evaluating the collected notes and tape recordings, the researchers came up with two major types of errors that students make; strong graph-as-picture confusion and weaker indication of slope/height confusion.

The second study was observational study that focused on examination of the ways in which students learn graphing skills through MBL. The researchers developed a MBL unit on motion as the intervention and the major goal of the unit was to teach middle school students to measure and plot position and velocity graphs. Students were asked to make many predictions and generate specific real-time graphs in the activities. During these five days of activities, observers recorded students' interaction with each other throughout the process. In addition to the observations, a quiz assessing students' mastery of distance and velocity graphs was administered on the final day. Both of the



results from observations and the quiz indicated that students developed solid graph interpretation skills.

After the observational study, a quasi-experimental study was designed about the impact of MBL on children's graphing skills. This study had two components; a multiple-choice test of graphing skills and a "think-aloud interview". One of the major goal of this study was to determine how middle school children's graphing skills develop over the course of three months' work with MBL in science class (Mokros & Tinker, 1987). The researchers developed a multiple-choice test and administered it to 125 seventh and eighth grade students on a pre- and posttest basis. Some test items were adapted from tests developed by McKenzie and Padilla (1994) and by Linn (1985) and others were designed by TERC staff. The researchers also conducted interviews to document students' skills in generating hypotheses, gathering data, observing and analyzing the graphs that emerged from the experiment, and drawing appropriate conclusions. Forty eight students participated to the experiment in which they collected real-time data. In the part of the interview, students were asked to make predictions about the light vs. time graphs and they were also shown a picture of a graph that doubled back in time and asked to explain if anything were wrong with the graph.

In the intervention, all seven classes worked with MBL units in heat and temperature, motion, sound and illusions over the course of three months. The classroom teacher also received four hours of training in using MBL materials. The intervention included a minimum of 20 class sessions that emphasized hands-on MBL activities on the units; the illusions unit, the heat and temperature unit, the sound unit and the motion unit.

Students worked in groups of 2-5 at their labs stations and each of them was given a computer.

Scores on the 16 graphing items showed a significant change in students` ability to interpret and use graphs between pre- and posttests. Students` understanding of graph-as-picture was largely disappeared by posttesting as it was evidenced by 77% correct response rate compared to 13% correct response rate in the pretest.

The researchers attribute the MBL success on four possible reasons: MBL uses multiple modalities which provide not only visual, but also auditory instruments; it pairs real-time events with their symbolic representations; it provides scientific experiences; and it diminishes the burden of graph production.

Adams and Shrum (1990) conducted a study to understand the effects of MBLs and level of cognitive development of tenth grade biology students` ability to construct and interpret line graphs.

Participants of this study were 46 students enrolled in general biology classes at a rural high school in Georgia during 1986-87 school year. After being tested about the level of cognitive development and graphing ability, 20 students were chosen to be participants of this study. All 20 students were also interviewed about graphing strategies. These students were assigned to either high or low achieving cognitive development groups depending on their score on the Group Assessment of Logical Thinking (GALT) (Roadranka, Yeany & Padilla, 1983) instrument. The low group was selected according to GALT scores from one to three and the high group with GALT scores from six to ten. Students then assigned to experimental or conventional groups based on their scores on

the Test of Graphing in Science (TOGS) (McKenzie & Padilla, 1986) and their sex. As a result, a balanced design from both GALT and TOGS scores and gender was achieved. After that all students attended specially designed four one-hour laboratory exercises which was examined by a panel of five science educators and were found to be appropriate practice on graphing skills for both groups.

Ten experimental group students completed laboratory exercises using a computer interfaced with probes for collecting, displaying, and graphing data. And the other ten students in the conventional group completed the same laboratory exercises using stopwatches, thermometers, pencils, papers to do the same things.

Students' ability to construct and interpret line graphs was assessed immediately after the lab treatments using open-ended version of the TOGS instrument called I-TOGS. It was designed to assess individually not the entire class. The only difference between TOGS and I-TOGS instrument was that there were no multiple-choice items in the latter. After that all students were interviewed about the reasons for their answers on the graphing instrument. Experimental group additionally had to complete several supplemental graphing tasks to determine the effects of practicing line-graph construction.

Results of this study indicated that the conventional group performed better in graph construction when compared to the experimental group. According to the researchers this result, however, is normal, because the conventional laboratory group has a lot more practicing opportunity of line graph construction than the MBL group. Students had several experience of graph construction by hand rather than seeing the

graph on the screen. And the researcher gave the MBL group more line graph construction practices, but when tested with I-TOGS they did not result in an increase of their scores. This was explained as students feeling of “burned-out” and their lack of willingness in identifying and correcting errors on I-TOGS instrument.

Although students experiencing MBL laboratory exercises may be better at performing graph-interpretation skills than students experiencing conventional laboratory exercises, but this was not evident in this small size of students. The difference was not significant between the groups. The students in MBL group mentioned when they were asked to use graph-interpretation skills on the I-TOGS instrument that they had a “mind’s eye” picture of laboratory events not available to students conducting laboratory exercises in the conventional manner. Student treated with MBL remember the graph behavior when different treatments applied.

Students classified as high cognitive development level showed a higher score on the graph-construction portion and graph-interpretation portion of the I-TOGS instrument than did low cognitive development level students. Number of students ( $n = 20$ ) participated in this study is one of the weakness of this study. The number of students is small and it does not adequately reflect all levels of student ability and cognitive development to assure complete external validity.

**Summary.** The 3 studies (Brasell, 1987; Nicolaou, 2007; Mokros & Tinker, 1987) above come to the same conclusion that students showed significant increase in learning gains in graph interpretation when supported with MBL. However, Adams and Shrum (1990) reported that there was no statistically significant difference between students taught with

MBL and students taught with conventional methods on their graph interpretation abilities. Adams and Shrum (1990) also reported that students taught with conventional methods outperformed students taught with MBL on graph construction tasks. The success of MBL was attributed to its nature that provides direct scientific experience of the phenomenon (Mokros & Tinker, 1987), its characteristics of having multiple modalities such as visual and auditory (Mokros & Tinker, 1987), diminishing the burden of graph production (Mokros & Tinker, 1987), and its time saving capability in data gathering and evaluating process, so allowing more time to focus on observation, discussion and reflection (Nicolaou et al., 2007). It has been reported that students' understanding of graph-as-pictures was largely disappeared by the treatment of MBL in the study of Mokros and Tinker (1987). Nicolaou et al. (2007) suggested that the specifically designed inquiry-oriented curriculum supported with MBL was effective because MBL allows students to simultaneously experience the results of their own manipulations during inquiry activities and MBL enables teachers spent more time on conceptual understanding by decreasing the data collection time.

## **Conclusion**

The 6 studies (Zucker et al., 2008; Avraamidou et al. 2008; Yerric & Johnson, 2009; Gado et al., 2006; Nicolaou et al., 2007) above come to the same conclusion that probeware use in inquiry-based learning environments positively affects students learning gains. With the integration of probeware, the inquiry-based learning environment in science teaching was shown to benefit students' understanding of science concepts such as sound, electricity, temperature and motion at 3-8 grade levels (Zucker et al., 2008).

Integration of probeware with inquiry-based teaching was also effective in improving middle school students' understanding of topics such as force-motion, energy transformations, metric system, matter, atoms, heat, wave motion, and water quality (Metcalf & Tinker, 2004; Yerrick & Johnson, 2009; Avraamidou et al., 2008). Moreover, integration of probeware with inquiry-based teaching led significant learning gains with regard to the topics such as Newton's 3<sup>rd</sup> law and conservation of momentum of high school physics students (Dimitriadis et al., 2000). Marcum-Dietrich and Ford (2002) reported that traditional biology labs supported with probeware improved 10<sup>th</sup> grade biology students enzyme action knowledge and data interpretation ability better than traditional labs with no probeware support.

In addition, students showed more interest and higher motivation in the process of implementation of probeware in the studies (Yerrick & Johnson, 2009; Avraamidou et al. 2008). Moreover, teachers reported that they needed less time to cover the content that they were teaching (Yerrick & Johnson, 2009).

The all 3 studies (Gado et al., 2006; Lyublinskaya & Zhou, 2008; Smith & Heaton, 2005) had the same conclusion that either preservice or inservice teachers are needed to be trained in a way that they will understand the benefits and promises of the integration of MBL and as a result feel confident to integrate MBL into their teaching. Lyublinskaya and Zhou (2008) showed that even if teachers' accepts the benefits of MBL, it may not affect their confidence in using MBL. Gado et al. (2006) reported that pedagogical practices that aim to infuse inquiry-based activities into science methods courses would have substantial effect on teachers' future MBL implementation decisions.

Four studies (Gado et al., 2006; Yerrick & Johnson, 2009; Nicolaou et al., 2007; Marcum-Dietrich & Ford, 2002) also suggested that MBL reduces the time needed for data acquisition and organization and so allowing more time for experimental design and interpretation.

The 5 studies (Royuk & Brooks, 2003; Mandryk et al., 2001; Bernard, 2001; Zucker et al., 2008; Yerrick & Johnson, 2009) above come to the same conclusion that students showed higher engagement and excitement while learning in MBL environment. The results from these studies implies that to get higher student learning gains, MBL are needed to be used both as technological and cognitive tool (Bernard, 2001), in a collaborative environment (Mandryk et al., 2001). When student were asked and let to design their own preference of handheld device, they chose and drew small and portable that is accessible almost everywhere (Inkpen, 1999). Students were able to understand and use scientific reasoning with BIODIDS Sequence and PDA (Personal Digital Assistant) in a particular study (Parr et al. 2004).

The 4 studies (Dimitriadis et al., 2000; Nicolaou et al., 2007; Metcalf & Tinker, 2004; Mokros & Tinker, 1987) above come to the same conclusion that students showed significant increase in learning gains in graph interpretation when treated with MBL (Microcomputer-based Laboratory). The success of MBL was attributed to its nature that provides direct scientific experience of the phenomenon (Mokros & Tinker, 1987), its characteristics of having multiple modalities such as visual and auditory (Mokros & Tinker, 1987), diminishing the burden of graph production (Mokros & Tinker, 1987), and its time saving capability in data gathering and evaluating process, so allowing more

time to focus on observation, discussion and reflection (Nicolaou et al., 2007). It has been reported that students' understanding of graph-as-pictures was largely disappeared by the treatment of MBL in the study of Mokros and Tinker (1987). One of the studies (Nicolaou et al., 2007) suggested that the success of their specially-designed, MBL integrated, inquiry-based curriculum was due to the fact that students experienced the phenomena directly, the sequence of concepts were shown in a way that lead to evolving of the meaning in students' minds, devoted time and care to let students develop conceptual understanding and lastly showing students that data-logging is not the end process.



## CHAPTER 3

### METHODOLOGY

#### **Participants**

Two fourth grade classes of a charter school in Las Vegas agreed to participate in this study. One of the classes was randomly assigned as the technology group (19 students, 9 male and 10 female) and the other class served as the conventional group (20 students, 11 male and 9 female). Average age of students in both technology group and conventional group was 10 years. The charter school started in 2007-2008 academic year. The school was designated as a high achieving school in 2007-2008 and 2008-2009 academic years and the school met adequate yearly progress (AYP) requirement in 2009-2010 academic year.

#### **Interventions**

Two physical science concepts (motion and temperature) provided a context to teach 4<sup>th</sup> grade students mathematical concept of graphing. Design of the intervention was heavily influenced by guided-inquiry teaching method (NRC, 1996). All guided-inquiry lessons were modeled after 5-E learning cycle lesson plan format (Bybee et al., 2006) (See Appendix A). Intervention was conducted by the researcher all the time. Technology group' guided-inquiry lessons related to motion and temperature were supported with laptop computers equipped with motion and temperature probes, and real-time graphing software. Conventional groups' guided-inquiry lessons related to motion and temperature were supported with traditional laboratory apparatus such as measuring tapes, meter sticks, and thermometers.

### Technology group

Mathematical concept of graphing was first introduced through a guided-inquiry lesson about motion and then concept of graphing was further introduced through a guided-inquiry lesson about temperature. Each lesson took 3 hours. Whole intervention took total 6 hours.

**Motion lesson.** Students were assigned to groups of three or four and they were given a demonstration about using laptop computers equipped with a motion detector and real-time graphing software. Then students were taken to schoolyard and they were given a series of moves. Students were asked to perform these moves in sequence in front of the motion detector in the schoolyard. While one student was performing the move, other members of the group watched the real-time graph (distance-time) as it was created on the laptop monitor.

Distance-time moves:

1. Motion slowly away from the detector
2. Motion quickly away from the detector
3. Motion slowly toward the detector
4. Motion quickly toward the detector
5. Standing still near the detector
6. Standing still far from the detector
7. Moving away, changing direction, and returning to the detector

After each group completed the moves they returned to the classroom. Then the relationship between each move and its corresponding graph was explained by the

instructor. For example, when a student slowly moves away from the detector, this is represented as a straight line starting from the origin with a relatively small positive slope. When a student quickly moves away from the detector, this is represented as a straight line starting from the origin with a relatively large positive slope. After the instructor finished explaining the relationship between each move and its corresponding graph, two application type questions were asked to students. The first question asked students to draw the distance-time graph of a certain move (see Appendix B). The second question asked students to describe the move that was represented in a graph (see Appendix B).

**Temperature lesson.** Groups formed during the motion lesson were kept the same. Students were given a demonstration about using laptop computers equipped with a temperature probe and real-time graphing software. Students were given about 10 minutes to explore the laptop computer and the temperature probe. They measured the temperature of various objects and materials in the classroom during this time. Given the required materials, students then performed the following procedure:

1. Measure the temperature of 200 mL of tap water in your beaker about 50 seconds.
2. Carefully put one ice cube in your beaker and stir it slowly with your temperature probe until it melts
3. Place your beaker on the hotplate and heat the water in your beaker about 100 seconds
4. Ask your instructor to take the beaker off of the hotplate

5. Carefully put 1 ice cube in your beaker and slowly stir it with your temperature probe until it melts

Instructor specifically warned students about hot plates which were carefully placed to prevent any hazard during the procedure. As students followed the procedure, the corresponding graph was created instantaneously on the monitor. However, the instructor also pointed out the effect of heating and cooling on the real-time (temperature-time) graph. After the instructor finished explaining how heating and cooling were represented in the real-time (temperature-time) graph, the instructor performed the following procedure by using required materials, one laptop computer and one temperature probe.

1. Measure the temperature of 200 mL of tap water in your beaker about 50 seconds.

2. Place the beaker on the hotplate and heat the water in the beaker about 100 seconds.

3. Take the beaker off the hotplate.

4. Carefully put 1 ice cube in the beaker and slowly stir with the temperature probe until it melts.

5. Carefully put 1 more ice cube in the beaker and slowly stir with your temperature probe until it melts.

6. Place the beaker on the hotplate and heat the water in the beaker about 100 seconds.

Students were not allowed to see the computer screen as the real-time (temperature-time) graph was produced during the procedure. After the procedure was over, students were asked to predict how the temperature-time graph produced during the procedure might look like. Students were given an opportunity to discuss their predictions with their group members and to reach into a consensus about their predictions. After students reached into a consensus, each group presented their predictions to the whole class. Finally, students were allowed to compare and contrast their predicted temperature-time graphs with the graph produced by the computer.

#### Conventional group

Mathematical concept of graphing was first introduced through a guided-inquiry lesson about motion and then concept of graphing was further introduced through a guided-inquiry lesson about temperature. Each lesson took 3 hours. Whole intervention took total 6 hours. Laptop computers equipped with motion and temperature probes, and real-time graphing software were not used for the conventional group. Instead, traditional laboratory apparatus were used throughout following lessons.

**Motion lesson.** Students were assigned to groups of three or four. Students were shown how a plastic water bottle with a small hole underneath can be used to detect how fast or slow a person moves. Each group was provided with a plastic water bottle with a small hole underneath. These bottles were prepared in a way that they allowed one water drop per second. Each group was asked to perform the following moves by holding the plastic water bottle in the schoolyard. The distance between the two water drops indicated how fast or slow a person moved.

Distance-time moves:

1. Motion slowly away from starting point
2. Motion quickly away from starting point
3. Motion slowly toward the starting point
4. Motion quickly toward the starting point
5. Standing still near the starting point
6. Standing still far from the starting point
7. Moving away from the starting point, changing direction, and returning to the starting point

Before students performed these moves, they were provided with data tables that allowed to record data about each move (see Appendix B). Students then used these data tables to create distance-time graphs for each move. After student finished creating their graphs, the relationship between each move and its corresponding graph was explained by the instructor. For example, when a student slowly moved away from the detector, this was represented as a straight line starting from the origin with a relatively small positive slope. When a student quickly moved away from the detector, this was represented as a straight line starting from the origin with a relatively large positive slope. After the instructor finished explaining the relationship between each move and its corresponding graph, two application type questions were asked to students. The first question asked students to draw the distance-time graph of a certain move (see Appendix B). The second question asked students to describe the move that was represented in a graph (see Appendix B). Students were given an opportunity to discuss their responses

with their group members and to reach into a consensus about their responses. After students reached into a consensus, each group presented their responses to the whole class. Finally, students were given a chance to revise their responses based on the whole class discussion.

**Temperature lesson.** Groups formed during the motion lesson were kept the same. The instructor demonstrated how to use a thermometer. Then students were given about 10 minutes to measure the temperature of various objects and materials in the classroom. Given the required materials, students then performed the following procedure:

Temperature-time procedure:

1. Measure the temperature of 200 mL of tap water in your beaker about 50 seconds.
2. Carefully put 1 ice cube in your beaker and stir it slowly with your thermometer until it melts
3. Place your beaker on the hotplate and heat the water in your beaker about 100 seconds
4. Ask your instructor to take the beaker off of the hotplate
5. Carefully put 1 ice cube in your beaker and slowly stir it with your thermometer until it melts

Before students performed the procedure, they were provided with a data table that allowed to record temperature for every 10 seconds (see Appendix B). Students then used this data table to create their own temperature-time graphs. Student completed their

temperature-time graphs with the help of the instructor. After students finished creating their graphs, the relationship between the procedure and its corresponding graph was explained by the instructor. Then the instructor performed the following procedure.

1. Measure the temperature of 200 mL of tap water in your beaker about 50 seconds.
2. Place the beaker on the hotplate and heat the water in the beaker about 100 seconds.
3. Take the beaker off the hotplate.
4. Carefully put 1 ice cube in the beaker and slowly stir with the thermometer until it melts.
5. Carefully put 1 more ice cube in the beaker and slowly stir with your thermometer until it melts.
6. Place the beaker on the hotplate and heat the water in the beaker about 100 seconds.

After the procedure was over, students were asked to predict how the temperature-time graph of this procedure might look like. Students were allowed to compare and contrast their predicted temperature-time graphs with their group members. After students reached into a consensus, each group presented their predictions to the whole class. Students were given a chance to revise their predictions based on the whole class discussion. Finally, students were asked to compare their predictions to the answer provided by the instructor.



## **Data collection**

Both at the beginning and at the end of the interventions, students were given three questions about motion (Keeley & Harrington, 2010) and three temperature questions prepared by the researchers (see Appendix C). The test comprised of 6 multiple-choice questions. Three of these questions measured students' ability to interpret representations of distance and time, and other three items measured students' ability to interpret graphical representations of temperature and time. Students were given ample time to answer each question and they were asked to provide an explanation for their answer. Students were also interviewed at the beginning and at the end of the intervention. A total of 28 students were chosen for follow-up interviews. Eight students (2 students from the technology group and 6 students from the conventional group) were interviewed immediately after the pre-administration of the test at the beginning of the intervention and the remaining 20 students (9 students from the technology group and 11 students from the conventional group) were interviewed immediately after the post-administration of the test at the end of the intervention. Interviews were important to establish the validity of the test and not to misinterpret the students' responses. Students were provided with their pre- or post-intervention tests and asked to explain their written responses. Follow-up questions were asked to clarify students' verbal explanations or justifications of their written responses. All interviews lasted about 25 minutes, were audio-taped and transcribed for analysis.

Two video cameras were carefully positioned to record each lesson in technology and conventional group. One of these cameras was recording the classroom as a whole,

while the other one was collecting data from one randomly selected group's work throughout the sessions. These two different recordings were useful in analyzing students' ability to interpret graphical representations of temperature-time and distance-time.

### **Data analysis**

The first round of data analysis focused on validating students' test responses through their written and verbal explanations. After validating students' responses in pre and post-test, means, standard deviations, maximum and minimum scores for both technology group and conventional group were calculated. Students' written and verbal explanations in the pre and post-test indicated that all students misinterpreted the third motion question. They viewed the graph provided in the question as an inclined plane. For this reason, this question was removed from the analysis. To determine whether the intervention was effective in improving both technology and conventional groups' ability to interpret graphical representations of temperature-time and distance-time, two dependent-samples t-tests were performed. The data were analyzed using Statistical Package for the Social Science (SPSS 17.0).

## CHAPTER 4

### RESULTS

Means, standard deviations, maximum and minimum scores for both technology and conventional group in pretest and posttest are presented in Table 1.

Table 1|  
*Means, standard deviations, maximum and minimum scores for both technology and conventional groups in the pretest and the posttest*

		Mean	SD	Max.	<u>Min.</u>	<u>t</u>	Effect size
Technology	Pre	2.39	.78	3	1	-2.03*	0.64
	Post	2.89	1.13	5	1		
Conventional	Pre	2.85	1.04	5	1	-0.51	0.14
	Post	3.00	1.21	4	0		

p<.05

Assumptions of normality of sampling distributions and linearity were not violated. The first dependent samples t-test indicated that the technology group performed significantly better in the post-test compared to the pre-test ( $t = -2.3, p < .05$ ). The second dependent samples t-test revealed that there was no statistically significant difference between pre- and post-test results of the conventional group.

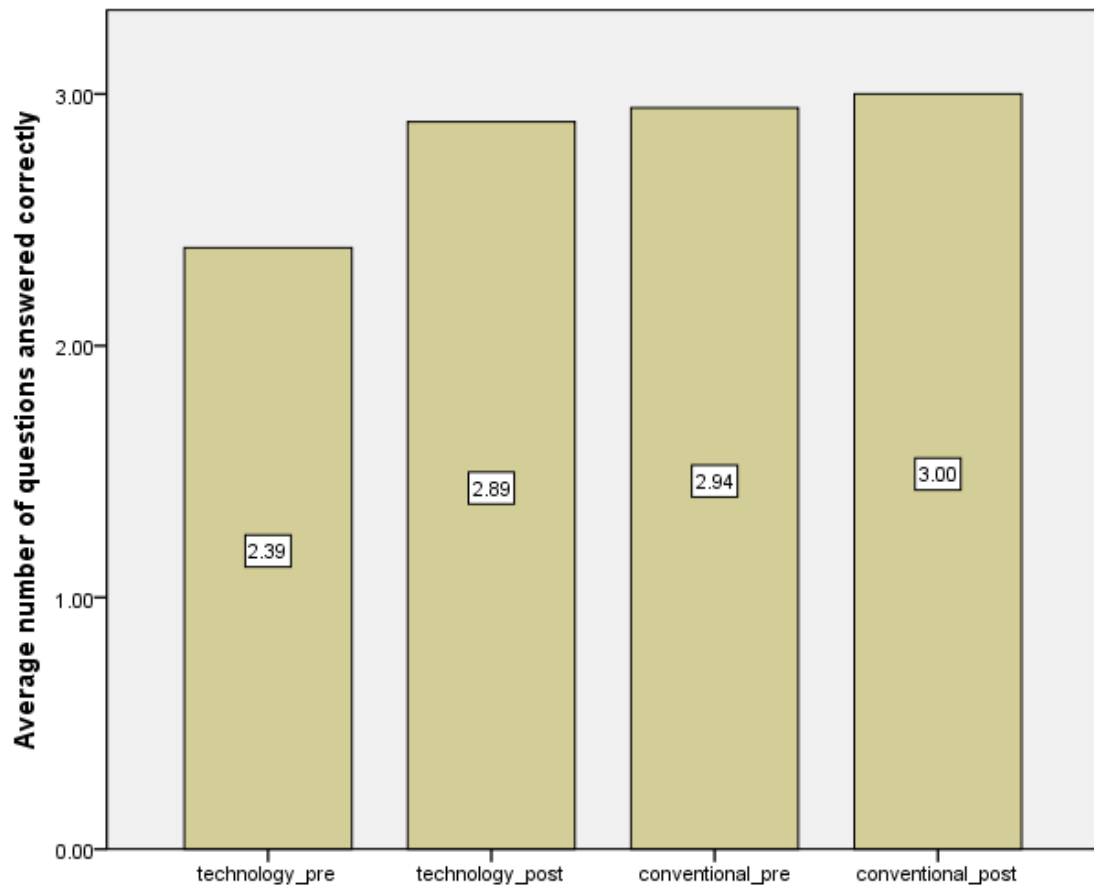


Figure 1. Average number of questions answered correctly by technology and conventional group students in the pretest and the posttest

An independent samples t-test indicated that the difference between technology and conventional groups' pretest results was not statistically significant ( $t = -1.53$ ,  $p = .13$ ). Levene's test of equality of error variances indicated that homogeneity of variance assumption was not violated ( $F = 0.464$ ,  $p = 0.50$ ) for the first independent samples t-test. Another independent samples t-test revealed that the difference between technology and conventional groups' posttest results was also not statistically significant. Levene's test of equality of error variances indicated that homogeneity of variance assumption was not violated ( $F = 0.656$ ,  $p = 0.42$ ) for the second independent samples t-test. However,

examination of the line graph showing changes in technology and conventional groups' pre and posttest results suggest that the difference between technology and conventional groups' posttest results is smaller than the difference between their pretest results.

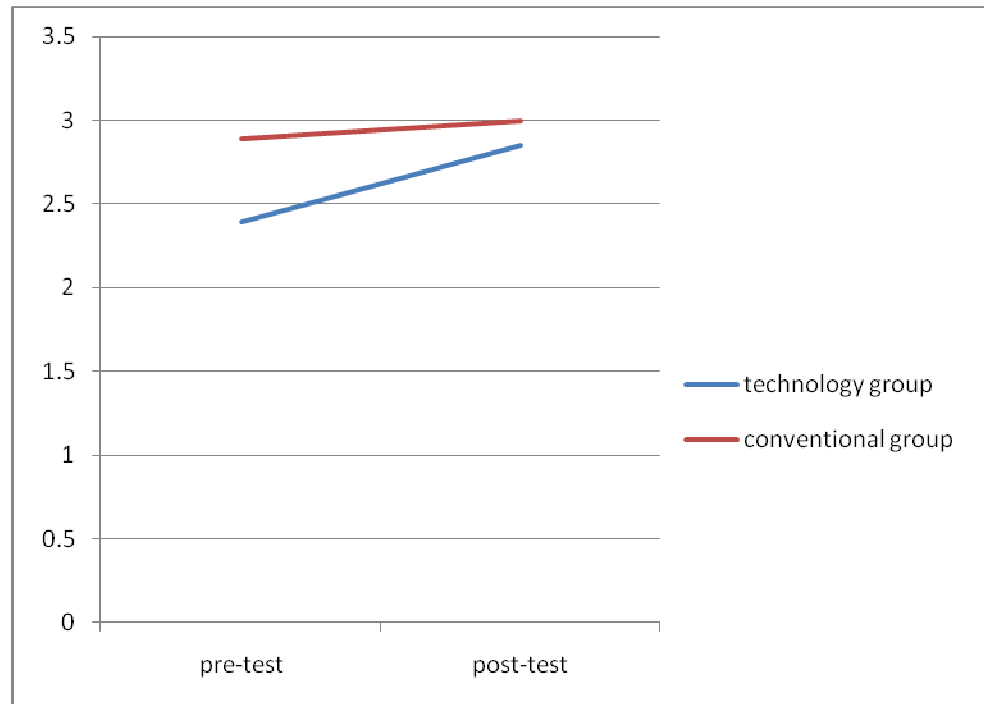


Figure 2. Average number of questions answered correctly by technology and conventional groups in pre and posttests

## Discussion

The findings of this study indicate that there is a significant advantage in using MBLs to support fourth graders' ability to interpret graphs. The data analysis revealed significant differences between pre and posttest results of the technology group. Students' ability to interpret graphs improved substantially more with the use of MBLs. The data analysis also revealed that there is no significant difference between pre and posttest results of the conventional group. In this study, the combination of the MBL and the inquiry-oriented lesson planning was found to be more effective than the combination of

inquiry-oriented lesson planning with conventional laboratory instruments in improving fourth graders' ability to interpret graphs.

The findings of this study are parallel to the findings of researchers (Zucker et al., 2008; Avraamidou et al. 2008; Yerrick & Johnson, 2009) who came to the conclusion that inquiry-based learning environments supported with MBLs positively affect students' learning gains. More specifically, the findings of this study support the findings of Nicolaou et al. (2007). Nicolaou et al. (2007) found that inquiry-curriculum supported with MBLs was more effective than inquiry-oriented curriculum supported with conventional instruments and traditional curriculum in improving fourth graders' ability to interpret graphs. The findings of this study are also parallel to the findings of other studies (Brasell, 1987; Mokros & Tinker, 1987) which came to the conclusion that students showed significant gains in their graphing skills as a result of MBLs. However, Adams and Shrum (1990) reported that there was no statistically significant difference between students taught with MBL and students taught with conventional methods on their graph interpretation abilities, but students taught with conventional methods outperformed students taught with MBL on graph construction tasks.

The effectiveness of MBL can be attributed to three different factors. First, MBL gives students the opportunity to watch the graph being produced as the experiment progresses (Brasell, 1987; Mokros & Tinker, 1987; Thornton, 1986). This gives students an opportunity to make a concrete connection between the physical phenomenon and its graphical representation. Second, computer allows students to finish their tasks substantially faster than their conventional counterparts (Beichner, 1990; Yerrick &

Johnson, 2009). For this reason, students using MBLs have the opportunity to spend more time on observation, reflection, and discussion (Roger, 1995; Yerrick & Johnson, 2009). Third, students show higher engagement with science content in MBL supported environments (Bernard, 2001; Mandryk et al., 2001; Royuk & Brooks, 2003). This can be due to the fact that movement in a computer screen captures students' attention (Brasell, 1987).

Considering the advantages of MBL and findings of studies mentioned above, it is reasonable to suggest that science teaching should be supported with MBLs when appropriate. For this purpose, teachers are needed to be trained in a way that they are competent enough to integrate MBLs in their teaching (Gado et al., 2006; Smith & Heaton, 2005; Lyublinskaya & Zhou, 2008). If teachers do not have adequate training in using MBLs, they may not have confidence to integrate MBLs in their teaching even if they accept the advantages of MBLs.

### **Limitations of the Study**

This study was conducted with two very small sample sizes. The technology group included 19 students and the conventional group included 20 students. Therefore, it may be unreasonable to assume that the results of this study are generalizable. The duration of intervention was relatively short. Motion and temperature lessons took total 6 hours. Intervention covered graphical representations of only motion and temperature. Graphical representations of other physical science concepts such as force, light, pressure, and sound were not covered. The findings of this study are relevant to fourth graders' ability to interpret graphical representations of motion and temperature. These

findings are not relevant to students' ability to construct graphical representations of motion and temperature. Adams and Shrum (1990) found that students taught with conventional methods outperformed students taught with MBL on graph construction tasks. Students in the conventional group might have better graph construction abilities than their counterparts in the technology group, but this study simply did not assess students' ability to construct graphs.



## APPENDIX A

### LEARNING CYCLE LESSON PLAN FORMAT OF MOTION AND TEMPERATURE LESSON

Motion Lesson	
Engagement	Students were divided into groups of three and they were given a demonstration about using laptop computers equipped with a motion detector and real-time graphing software. On the other hand, students in conventional group were informed about measuring tapes and necessary equipment that will be using in the activity part.
Exploration	Students were given a series of moves and asked to work through these moves in sequence. Distance-Time Moves 1. Move slowly away from the detector 2. Move quickly away from the detector 3. Move slowly toward the detector 4. Move quickly toward the detector 5. Standing still near the detector 6. Standing still far from the detector 7. Moving away, changing direction, and returning to the detector
Explanation	The relationship between each move and its corresponding graph was explained by the instructor.
Elaboration	In this phase, students were taken inside to their classroom and handed out Elaboration Moves questions.
Evaluation	Students' work were evaluated throughout the intervention by the instructor and teacher assistant.

Students in the conventional group did not use motion detectors. They used plastic water bottles to detect how fast or slow a person moves. Each group was provided with a plastic water bottle with a small hole underneath. These bottles were prepared in a way that they allowed one water drop per second. Each group was asked to perform the moves above by holding the plastic water bottle in the schoolyard. The distance between the two water drops indicated how fast or slow a person moved.

Temperature Lesson	
Engagement	Students were divided into groups of three and they were given a demonstration about using laptop computers equipped with a temperature probe and real-time graphing software. On the other hand students in conventional group were informed about thermometers and timers they need in the activity part.
Exploration	Instructor handed out the paper describing the procedures. 1. Measure the temperature of 200 mL of tap water in your beaker about 50 seconds. 2. Carefully put one ice cube in your beaker and stir it slowly with your temperature probe until it melts 3. Place your beaker on the hotplate and heat the water in your beaker about 100 seconds 4. Ask your instructor to take the beaker off of the hotplate 5. Carefully put 1 ice cube in your beaker and slowly stir it with your temperature probe until it melts
Explanation	The relationship between each step and its corresponding graph was explained by the instructor.
Elaboration	Instructor had students predict and draw graph of the following procedure below. 1. Measure the temperature of 200 mL of tap water in your beaker about 50 seconds. 2. Place the beaker on the hotplate and heat the water in the beaker about 100 seconds. 3. Take the beaker off the hotplate. 4. Carefully put 1 ice cube in the beaker and slowly stir with the temperature probe until it melts. 5. Carefully put 1 more ice cube in the beaker and slowly stir with your temperature probe until it melts. 6. Place the beaker on the hotplate and heat the water in the beaker about 100 seconds.
Evaluation	Students` work were evaluated throughout the intervention by the instructor and teacher assistant.

Students in the technology group did not use temperature probes. They used regular thermometers to collect data.

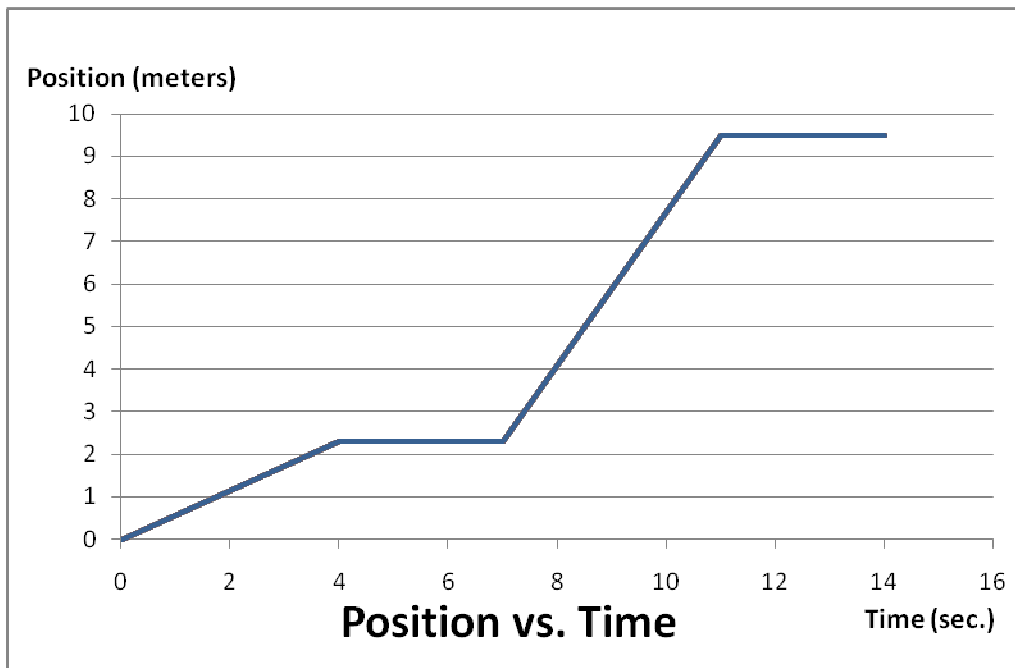
## APPENDIX B

### TECHNOLOGY AND CONVENTIONAL GROUP MOTION LESSON APPLICATION QUESTIONS

1. Please draw the distance-time graph of the following move.

Starting in front of the motion detector, walk quickly away from the detector for 5 seconds, stop for 4 seconds, and walk slowly away from the detector for 10 seconds

2. Please write down the move that is represented by the following graph.



Conventional group motion lesson sample data table:

**Distance versus Time Table for Move 1**

<b>Time (seconds)</b>	<b>Distance from the starting point (cm)</b>
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

Conventional group temperature lesson sample data table:

**Time versus Temperature Data Table**

<b>Time (seconds)</b>	<b>Temperature (°C)</b>
0	
10	
20	
30	
40	
50	
60	
70	
80	
90	
100	

## APPENDIX C

### PRETEST AND POSTTEST QUESTIONS

1. Josey and her little brother Jack are walking side by side, eating ice cream cones. Josey stops to talk to a friend. While she is talking, Jack's ice cream cone starts to drip at a steady rate as Jack walks away. When Josey finishes talking to her friend and realizes that Jack is no longer next to her, she looks down and notices these drops of ice cream on the ground from Jack's ice cream cone:



Josey needs help figuring out what Jack was doing. Circle the best answer that best shows how Jack moved (walked) while Josey stopped to talk to her friend.

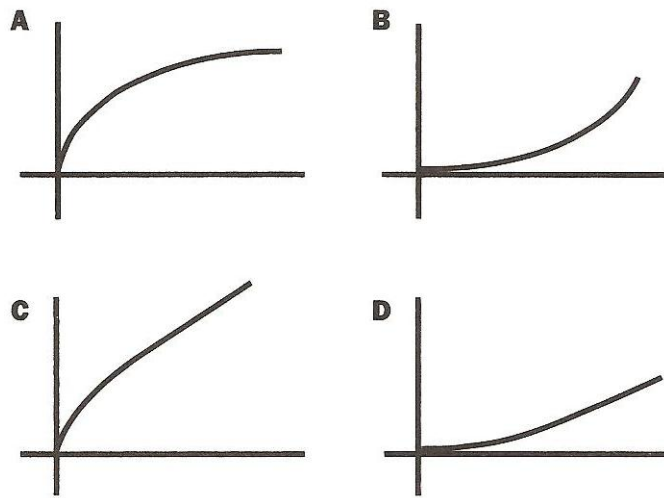
- A. The drips show that Jack started walking slowly and then went faster and faster.
- B. The drips show Jack started out walking really fast and then slowed down and went slower and slower.
- C. The drips show that Jack started out walking slowly, then walked faster and continued to walk at that same speed.
- D. The drips show that Jack started out walking fast, slowed down, and then continued to walk at that same, steady speed.

Explain your thinking. Provide an explanation for your answer.

2. Josey and her little brother Jack are walking side by side, eating ice cream cones. Josey stops to talk to a friend. While she is talking, Jack's ice cream cone starts to drip at a steady rate as Jack walks away. When Josey finishes talking to her friend and realizes that Jack is no longer next to her, she looks down and notices these drops of ice cream on the ground from Jack's ice cream cone:

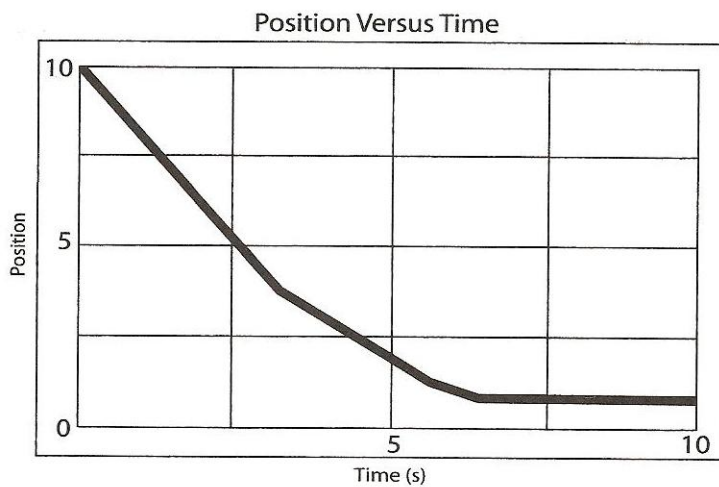


Josey needs help figuring out what Jack was doing. Which of the following position versus time graphs best show how Jack moved (was walking) while he was eating his ice cream cone? Circle the letter of the best graph?



Explain your thinking. Describe how the graph you chose best matches Jack's motion.

3.



Jim and Karen have built a go-cart. They take their go-cart for a test run and graph its motion. Their graph is shown above. They show the graph to their friends. This is what their friends say:

**Bill:** "Wow, that was a steep hill! You must have been going very fast at the bottom."

**Patti:** “I think you were going very fast at first, but then you slowed down at the end.”

**Kari:** “I think you must have hit something along the way and come to a full stop.”

**Mort:** “it looks like you were going downhill and then the road flattened out.”

Circle the name you think the best describes the motion of the go-cart, based on the graph. Explain why you agree with that friend.

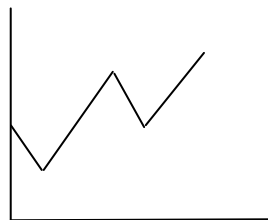
4. Jack is using a thermometer to measure the temperature of water in a can. He is heating and cooling the water in the can. He recorded his temperature measurements in the table below.

**Temperature of Water Measured by Jack**

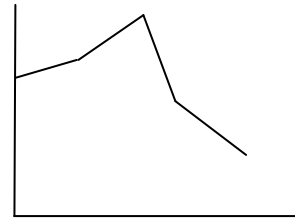
Measurement (Number)	Temperature (°C)
1	25
2	35
3	20
4	10
5	40

Can you help Jack to graph his recordings? Which of the following temperature versus time graphs best shows the recordings of Jack? Circle the letter of the best graph.

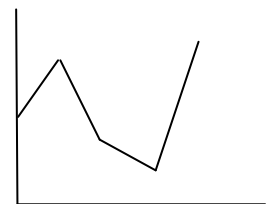
A



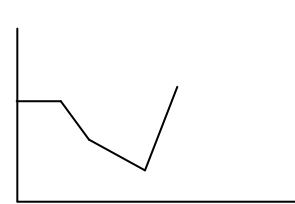
B



C



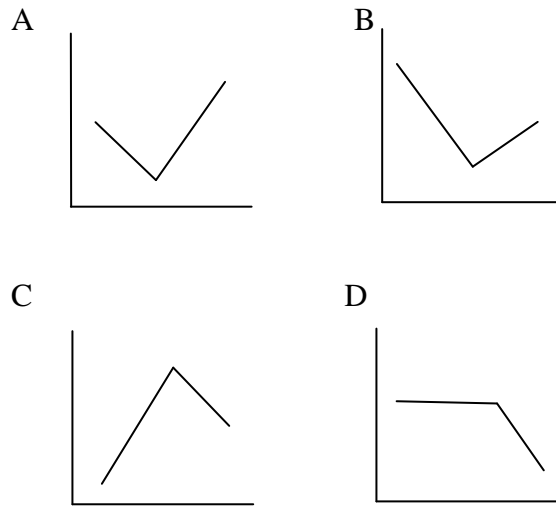
D



Explain your thinking:

5. Jim is feeling thirsty after playing with his friends outside. He goes home and grabs a bottle of water from the refrigerator. But he realizes that the water is too cold for him to drink. He places the water bottle outside under the sun for a while. Then he realizes that the water is too warm and he puts some ice in the water bottle.

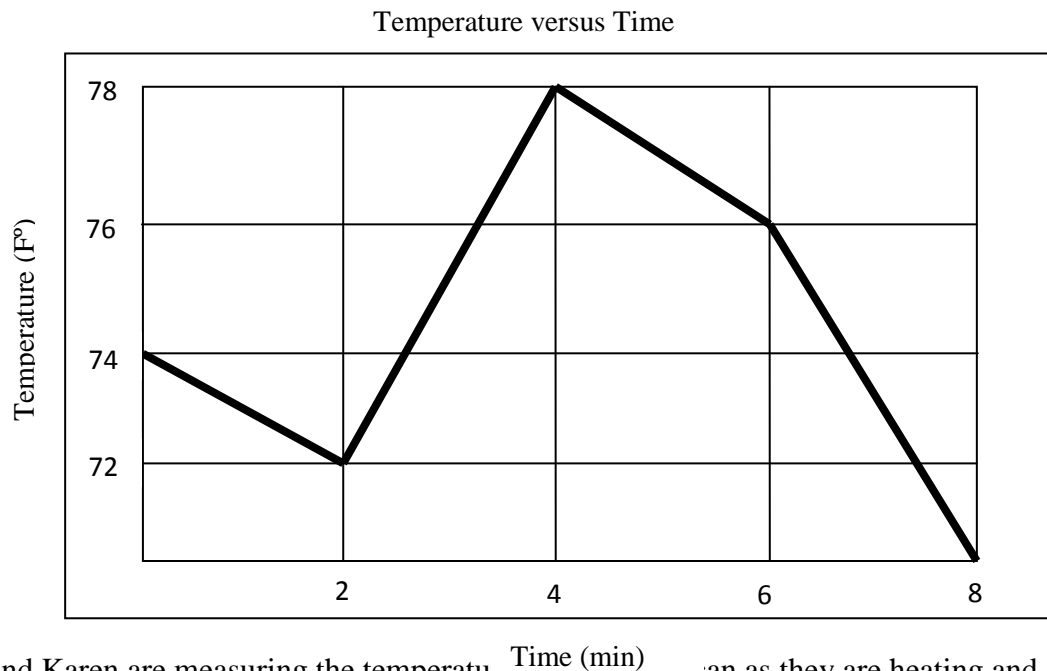
Which of the following temperature versus time graphs best shows how Jim's drinking water temperature changes? Circle the letter of the best graph.



Explain your thinking:



6.



Jim and Karen are measuring the temperature of the water in the can as they are heating and cooling the water. Their graph is shown above. Which of the following choices best shows how Jim and Karen heated and cooled the water in the can? Circle the letter of the best choice.

- A. heat, cool, heat, heat
- B. cool, heat, cool, cool
- C. heat, heat, cool, cool
- D. cool, cool, heat, heat

Explain your thinking:

## REFERENCES

- Adams, D. D., Shrum, J. W., (1990). The effects of microcomputer-based laboratory exercises on the acquisition of line graph construction and interpretation skills by high school biology students, *Journal of Research in Science Teaching*, 27(8) 777-787.
- American Association for the Advancement of Science (AAAS). (1993). Benchmarks for science literacy: A Project 2061 report. New York: Oxford University Press.
- Avraamidou, L., Evagorou, M., Demetriou, C., & Vrasidas, C. (2008). The use of handhelds in school science: A water quality study. In J. Luca & E. Weippl (Eds.), *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2008* (pp. 3995-4000). Chesapeake, VA: AACE.
- Beichner, R. J. (1990). The effect of simultaneous motion presentation and graph generation in a kinematics lab. *Journal Research in Science Teaching*, 27(8), 803–815.
- Bernhard, J., (2001). Physics learning and Microcomputer Based Laboratory (MBL) - Learning effects of using MBL as a technological and as a cognitive tool. *Proceedings of ESERA2001, Science Education Research in the Knowledge Based Society*, Thessaloniki, 21 - 25 August, 2001
- Brassell, H., (1987). The effect of real-time laboratory graphing on learning graphic representations of distance and velocity. *Journal of Research in Science Teaching*, 24(4), 385–395.
- Bybee, R.W., Taylor, A.J., Gardner, A., Scotter, P.V., Powell, J.C., Westbrook, A. & Landes, N. (2006). The BSCS 5E instructional model: Origins, effectiveness and applications. <http://www.bscs.org/pdf/bscs5eexecsummary.pdf> Accessed March 21, 2011.
- Dimitriadis, P., Papatsimpa, L., Kampouris-Papamihalis, K., Karanikas, G. & Kalkanis, G. (2000). The Study of Newtonian Mechanics in junior high school. A new technology - based learning environment. In J. Bourdeau & R. Heller (Eds.), *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2000* (pp. 1312-1313). Chesapeake, VA: AACE.
- Friedler, Y., Nachmias R., & Linn M. C., (1990). Learning scientific reasoning skills in microcomputer-based laboratories. *Journal Research in Science Teaching* 27(2), 173–191.
- Gado, I., Ferguson, R., & van't Hooft, M., (2006). Using handheld-computers and probeware in a science methods course: Preservice teachers' attitudes and self-efficacy. *Journal of Technology and Teacher Education*, 14(3), 501- 529.

Inkpen, K. M., (1999). Designing handheld technologies for kids. *Personal Technologies*, 3(1&2) 81-89.

Krajcik, J. S., & Layman, J., (1993). Microcomputer-based laboratories in the science classroom. Research that matters to the science teacher, no. 31. National Association of Research on Science Teaching (NARST).

Laws, P. (1997). Millikan lecture 1996: promoting active learning based on physics education research in introductory courses. *American Journal of Physics*, 65(1), 14–21.

Linn, M. C., Layman J. W., & Nachmias, R., (1987). Cognitive consequences of micro-computer-based laboratories: graphing skills development. *Contemporary Educational Psychology*, 12(3), 244–253.

Lei, J., & Zhao, Y., (2007). Technology uses and student achievement: A longitudinal study. *Computers and Education*, 49(2), 284-296.

Lyublinskaya, I., & Zhou, G., (2008). Integrating graphing calculators and probeware into science methods courses: Impact on preservice elementary teachers' confidence and perspectives on technology for learning and teaching. *Journal of Computers in Mathematics and Science Teaching*, 27(2), 163-182.

Mandryk, R. L., Inkpen, K. M., Bilezikjian, M., Klemmer, S. R., and Landay, J. A. 2001. Supporting children's collaboration across handheld computers. In *CHI '01 Extended Abstracts on Human Factors in Computing Systems* (Seattle, Washington, March 31 - April 05, 2001). CHI '01. ACM, New York, NY, 255-256.

Marcum-Dietrich, N. I. & Ford, D. J., (2002). The Place for the computer is in the laboratory: An investigation of the effect of computer probeware on student learning. *Journal of Computers in Mathematics and Science Teaching*, 21(4), 361-379.

Metcalf, S., Tinker, R. F., (2004). Probeware and handhelds in elementary and middle school science. *Journal of Research in Science Teaching*, 13(1), 43–49.

Millar, M., (2005). Technology in the lab, Part I: what research says about using probeware in the science classroom. *Science Teacher*. 72(7), 34–37.

Mokros, J. R., & Tinker, R. F. (1987). The impact of microcomputer-based labs on children's ability to interpret graphs. *Journal of Research in Science Teaching*, 24(4), 369-383.

National Resource Council (1996). National Science Education Standards, Washington D.C.: National Academy Press.

Nicolaou, C., Nicolaidou, I., Zacharia, Z., & Constantinou, C., (2007). Enhancing fourth graders ability to interpret graphical representations through the use of microcomputer-based labs implemented within an inquiry-based activity sequence. *Journal of Computers in Mathematics and Science Teaching*, 26(1), 75–99.

Parr, C. S., Jones, T., & Songer, N. B., (2004). Evaluation of a handheld data collection interface for science learning. *Journal of Science Education and Technology*, 13 (2), 233-242.

Pew Research Center. (2005). Trends 2005. Washington, D.C.: Pew Research Center. <http://www.pewresearch.org/assets/files/trends2005.pdf> Accessed March 27, 2011.

Royuk, B., Brooks, W. D., (2003). Cookbook Procedures in MBL Physics Exercises. *Journal of Science Education and Technology*, 12(3) 317-324.

Sabelli, N. (1995). For our children's sake, take full advantage of technology. *Computers in Physics*, 9(1), 2.

Smith, L. & Heaton, L. (2005). Integrating handheld computers in rural science classroom. In C. Crawford et al. (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2005* (pp. 3750-3754). Chesapeake, VA: AACE.

Yerrick, R., & Johnson, J., (2009). Meeting the needs of middle grade science learners through pedagogical and technological intervention. *Contemporary Issues in Technology and Teacher Education*, 9(3), 280-315.

Zucker, A. A., Tinker, R., Staudt, C., Mansfield, A., & Metcalf, S., (2008). Learning science in grades 3–8 using probeware and computers: Findings from the TEEMSS II Project, *Journal of Science Education and Technology*, 17, 42–48.

## VITA

Graduate College  
University of Nevada, Las Vegas

Mehmet Fatih Dulger

### Degrees:

Bachelor of Science, Elementary Science Education  
Middle East Technical University

### Special Honors and Awards:

UNLV Access Grant

Thesis Title: Using Graphs to Represent Physical Phenomena in a Fourth Grade Classroom

### Thesis Examination Committee:

Chairperson, Hasan Deniz, Ph.D.  
Committee Member, Kent Crippen, Ph.D.  
Committee Member, Janelle Bailey, Ph.D.  
Graduate Faculty Representative, Scott Loe, Ph.D.