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Going beyond cookbook labs: computer-based laboratory tools in the high school physics classroom

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Going beyond cookbook labs: computer-based laboratory tools in the high school physics classroom

Abstract
Physics education is currently undergoing a face lift. The lecture should no longer be the primary mode of instruction because students are not actively participating. For effective learning to occur, the students need to be engaged, not passive listeners (Knight, 2005). Student-centered classrooms are becoming more common, but there is still work to be done. For a student-centered classroom to be effective, the students must construct their own understanding with the teacher acting as a 'guide. Physics instructors are responsible for making the classroom a user friendly environment for students to explore the basic concepts of physics and to develop a conceptual understanding of physics.
GOING BEYOND COOKBOOK LABS: COMPUTER-BASED LABORATORY TOOLS IN
THE HIGH SCHOOL PHYSICS CLASSROOM

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In Partial Fulfillment
Of the Requirements for the Degree
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Chapter I

INTRODUCTION

Physics education is currently undergoing a face lift. The lecture should no longer be the primary mode of instruction because students are not actively participating. For effective learning to occur, the students need to be engaged, not passive listeners (Knight, 2005). Student-centered classrooms are becoming more common, but there is still work to be done. For a student-centered classroom to be effective, the students must construct their own understanding with the teacher acting as a guide. Physics instructors are responsible for making the classroom a user-friendly environment for students to explore the basic concepts of physics and to develop a conceptual understanding of physics.

A dynamic way to introduce these concepts is through the use of educational or instructional technology in the classroom. Elizabeth Kennedy (2001) gave a perfect example of dynamic science with her middle school classroom. The students were able to share basic motion graphs with the kindergarten and first-grade students in their school. The students set up a motion sensor with a display of the motion graphs for all the students to see. The younger students then tried to match motion graphs of already plotted data. The older students acted...
as coaches and worked to help the younger children “see” how motion affected the graphing. Standing still caused the position-time graph to become horizontal, moving toward the sensor steadily caused the graph to move downward diagonally and moving away steadily caused the line to move upward diagonally.

By using this information, the younger students were able to match motion graphs that had been created prior to the laboratory. All of the students were able to learn more about motion and the instructional technology allowed a deeper understanding of the concept of motion. The older students benefited because through their “coaching” they developed a deeper understanding of the concept of motion (Kennedy, 2001).

Statement of Research Question

Science teachers are expected to use innovative and effective methods to teach students science concepts. As our society becomes more technologically sophisticated, instructors are expected to implement the technology into their classrooms as well. The teachers need to understand how to integrate the technology into the classroom because it cannot replace good teaching practices. This paper will answer the question: How can computer-based laboratory tools be integrated and used effectively in the high school physics classroom?

Personal motivation

My interest in computer-based laboratory tools began when I
used Microcomputer-Based Laboratories (MBLs) and Calculator-Based Laboratories (CBLs) systems briefly during my undergraduate study at the University of Northern Iowa (UNI), 1992-1997. My first teaching placement, at Green Mountain Garwin in Garwin, Iowa, did not have these resources so I could not use them. My second placement at West Delaware High School in Manchester, Iowa, had a number of CBL systems and sensors. I used them in my physics class, but in a cookbook type fashion. We did the labs exactly as the lab manual stated and usually got great results. I however didn’t think the students were able to identify the underlying concepts. I left the school with a feeling that I needed to do more to make computer-based or calculator-based laboratory tools a rewarding and more inquiry-based experience. I changed jobs again before I could get started on that goal.

In 2000, I started at my current employer, Gladbrook-Reinbeck Community School District. Gladbrook-Reinbeck is a rural school district with an enrollment of 250 students at the high school. The science department had three CBL systems, but only a few sensors, which didn’t allow for whole class activities. In 2002, I was able to secure a McElroy grant to increase my CBL systems to six and add a number of probes. Having access to these resources increased my interest in the use of calculator-based laboratory tools in the classroom. I
started to use CBL systems with the motion detector to teach the topic of motion. However, I didn’t get much farther than that.

In the summer of 2005, I decided to make the successful integration of computer-based laboratory tools into the secondary physics and physical science classroom the focus for my research paper to complete my Masters of Education degree from UNI. I started work on this paper and began integrating computer-based laboratory tools more into my science classroom. During the summer of 2006, I was a participant in an initiative to improve science education across the state of Iowa using probeware as I continued to work on the paper. The program entitled Enhancing Education Through Technology, E2T2, was offered through the local Area Education Agency 267. Participating teachers were provided LabPro computer interfaces from Vernier Software and Technologies and a number of sensors along with other resources to integrate into their secondary science classrooms. Participants were provided professional development and support in using inquiry-based methods to integrate computer-based laboratory tools into their physics/physical science curriculum. This professional development and support was provided in one-week summer workshops, academic year meetings, and resources accessible to the participants.
Definition of terms

Computer-Based Laboratory Tool - Computer-based laboratory tools formerly know as MBLs or microcomputer-based laboratory tools include sensors, also known as probeware, interface, and data collection/analysis software used in combination with a computer. Various computer-based laboratory systems and calculator-based laboratory systems or CBLs exist. The system chosen depends on individual classroom needs such as funding, audience and intended activities.

Conceptual understanding - Conceptual understanding is the conceptual knowledge or knowledge of physical principles (Knight, 2004). According to Knight, conceptual knowledge has explanatory and predictive powers. Understanding of these principles signifies an ability to use them in new situations. The emphasis is not on the mathematical manipulation of variables.

Cookbook laboratory - This type of activity does not allow students to vary from the laboratory procedure. Students are expected to follow the provided directions step by step and to achieve the desired result. The students follow the given directions like a cook follows a recipe provided in a cookbook.

Discovery learning - Discovery learning is when learners are allowed to work through science in their own way and develop understanding on their own. They are given materials in an
activity and the students use it in any way they want. The teacher does not guide the students’ learning and provides minimal assistance.

**Educational or instructional technology** - Technology used to enhance students’ learning experiences and to improve the students understanding and application of concepts in the classroom. The technology is a tool for learning within the curricular area. Technology in the classroom can include word processing, spreadsheets, computer-based laboratory tools, streaming video, and concept simulation.

**Force Concept Inventory (FCI)** - Hestenes, Wells & Swackhamer (1992) developed the FCI to focus attention on student’s preconceived beliefs that do not agree with Newtonian physics. The assessment is a multiple choice test that sets commonsense beliefs against Newtonian physics. This assessment is recommended to be given to students before instruction as a pre-test and after instruction as a post-test to measure change in the students’ conceptual understanding as a result of instruction. The ideas of force are central to all Newtonian physics so this assessment can provide insights for instructors to guide their instruction (Hestenes, Wells & Swackhamer, 1992). The FCI is commonly used in physics education research as a
measure of students' conceptual understanding of force and motion (Knight, 2005).

**Inquiry based laboratory** - The National Science Education Standards (1996) defines inquiry as "a set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena; in doing so, students acquire knowledge and develop a rich understanding of concepts, principles, models, and theories" (p. 214).

**Interactive engagement techniques** - Interactive engagement techniques are ways to encourage students to be actively involved in the classroom. The students are actively engaged in the material being presented. They are doing not listening to physics. These techniques engage students in "hands-on" and "minds-on" activities with the focus on the content and continuing to ask questions (Knight, 2004).

**Learning cycle** - The learning cycle is a method of teaching science. It is a student-centered approach in which students investigate the physical phenomena related to concepts prior to these concepts being formally introduced. The concepts are then introduced within the context of these observations and then students are provided additional opportunities to reinforce and apply their understanding to new situations (Cooney et al.,
There are a couple of types of learning cycles that will be discussed further later in this paper.

**Probeware** - Sensors that connect to a computer-based or calculator-based laboratory tools to collect data in real time.

**Real-time data** - Physical data that is collected and displayed in graphical and/or tabular form instantaneously. With the appropriate computer-based laboratory tool set up, students can observe a graphical display of the data being collected as the physical phenomena occurs.

**Scientific inquiry** - The National Science Education Standards (National Research Council, 1996) defines inquiry as "a set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena..." The end product is a richer understanding of the theories and concepts developed through this process. Students are learning in the way that science actually works in the world around them.

**Socratic questioning** - Socratic questioning is an interactive engagement technique involving a type of questioning often used with student poster whiteboard discussions in physics classrooms. "The teacher strives to remain unobtrusively in control of the agenda throughout the discussion, never acting as an agent in inquiry to engage in a relationship.
an authority or a source of knowledge” (Modeling Instruction Program, 2008).

**Student misconception** - A preconception, naïve idea, or belief held by a student that is objectively false. In physics, these beliefs are often validated by everyday experiences. Teachers must deal with student misconceptions explicitly to help erase this incorrect information and create new models for conceptual understanding (Knight, 2004).

**Student-centered classroom** - A classroom in which science inquiry can thrive due to student contribution to the learning process. Teachers set up an environment with a focus on the students. Teachers plan instruction, but provide flexibility for modifications based on student contributions to the learning environment. The student’s interests and feedback guide classroom direction and focus. Students use hands-on and minds-on investigations to learn more about science.

**Teacher-centered classroom** - A classroom led by the teacher that minimizes student input and contributions. More emphasis is placed on traditional forms of instruction including lectures. Hands-on investigations may be used but they may be more cook-book in nature. There are few or no chances for science inquiry to happen in this environment.
Test of Understanding Graphics - Kinematics (TUG-K) - This assessment was developed by Robert Beichner to test for students' ability to read and understand kinematics graphs (Beichner, 1996). The TUG-K contains 21 multiple choice survey items that measure a student's ability to interpret motion graphs. The student must also be able to translate back and forth from words to graphs (Redish, 2003).

Traditional methods physics course - A traditional introductory physics course is a lecture-based course with validation and cookbook laboratories done to support the topics presented (Knight, 2005).

Organization of the Paper

This paper will address the changing face of physics education with an introduction to a high school inquiry-based physics classroom that integrates the use of computer-based laboratory tools. The final component will identify the components needed for successful integration of a computer-based laboratory system into the high school physics classroom. I will share the insights I have gained from participating in the E2T2 program and implementing the computer-based laboratory tools provided in my physics/physical science classroom. I will also provide some insights on the impact these resources have had on my instruction and student learning.

I have reviewed the literature and will use the insights
gained from this review and my personal teaching experiences to address this research question. I, however, will not be using any quantitative or qualitative student data collected from my classroom.
Chapter II

REVIEW OF THE RESEARCH

Introduction

Chapter two focuses on the trends in physics education and the use of computer-based laboratory tools in the classroom. It begins with a description of the recent trend towards more active, student-centered classroom. Succeeding sections describe the learning cycle and how the integration of technology can be used to facilitate this trend. The role of the computer-based laboratory tools in the classroom will also be discussed. Finally, a comparison of inquiry-based and cookbook laboratories will be made.

Trends in Physics Education

Physics education researchers have shown that traditional physics instruction, mainly the lecture-based course, is not reaching a majority of students (Redish, 2003). Knight (2004) discusses how to move beyond rote memorization. Without a conceptual understanding of the underlying concepts, the students are unable to successfully solve open-ended, indeterminate, real-world problems (Knight, 2004). Hake’s study, which is referenced in Knight’s book (2004), found a relationship between the conceptual understandings of the student’s scores on the FCI inventory. An active learning
environment resulted in more than twice the gain achieved in a traditional classroom setting (Knight, 2004). Instructors are continually seeking new methods to teach that foster better learning and conceptual understanding in their students. Conceptual understanding means students are able to use the information learned in different contexts with little guidance. The students are able to find similarities in different situations. Although, Redish was referring to introductory physics courses at the university level, this applies to high school physics courses as well.

"The fact that the mind works by context-dependent patterns of association suggests that students reason about physics problems using what they think they know by generalizing their personal experience" (Redish, 2003, p. 25). Students enter classrooms with a set of life experiences. Not all of what we observe is explainable with these insights. The instructor must help the students identify their errors in thought so that they can move forward in physics. An example of life experience not following the laws of physics is the phenomena of falling objects. If I drop a feather and a hammer from the same height here on earth, they should fall with the same acceleration and thus have the same speed the instant before they hit the ground, according to Newton’s laws if air resistance is ignored. However, we all know that is not the case because air resistance
cannot be ignored. Helping students to understand the reasons why these objects fall differently is a question that needs to be addressed to help students develop a conceptual understanding of the related physics ideas.

**Learning Cycle**

The learning cycle is a model for teaching in the science classroom in which concepts are introduced within the context of student investigations of the related physical phenomena and relevant applications. There are a few different learning cycle models.

Lorsbach (2008) discusses a 5E learning cycle. The five E's are:

- **Engage** - get students interested in the new topic,
- **Explore** - allow students to interact with materials without teacher instruction, but rather teacher guidance,
- **Explain** - students with the aid of the teacher put the concept in their own words,
- **Extend** - students apply their new concept to similar situations to practice using the new terms and situations, and
- **Evaluate** - this portion happens as during all the other stages as teachers ask open-ended questions to focus students thinking.
Another learning cycle model contains three main parts. The three stage learning cycle is used by Physics Resources and Instructional Strategies for Motivating Students (PRISMS) PLUS—a high school physics curriculum developed at the University of Northern Iowa or UNI (Cooney, Escalada and Unruh, 2005).

- Exploration - students are introduced to new material and must make observations and find patterns.
- Concept development - concepts are developed within the context of what they observed.
- Application - opportunities for students to apply their understanding of concepts to new situations and real-life problems.

Both of these models allow the students to start with a common experience and then work towards conceptual understanding. The students work through inquiry laboratories for these stages to occur. The differences are in how the teacher is involved in the process. Although the PRISMS PLUS materials utilize the three stage learning cycle, the curriculum also includes student and teacher materials that are consistent with the 5E learning cycle.

Modeling instruction uses a modified learning cycle. The Modeling Cycle which contains two stages, model development and model deployment. The model development includes the exploration stage of the typical learning cycle. The model
deployment involves the application stage. Each modeling cycle is designed to be flexible so it can be adapted to any physics topic. The modeling cycle takes two to three weeks for completion depending on the topic covered.

Knight (2004) refers to an effective learning cycle as being able to confront student misconceptions and to examine wrong predictions closely. Alternative models need to be introduced and then repeated to show that the new information can replace the misconception that was held at the start of the activity. “Physics education research has brought out the need for instruction to be student-centered, explicitly recognizing the knowledge state of the students and the activities that will transform them to the desired state” (Knight, 2004, p. 41).

Student-centered classrooms promote student interactions and help identify those misconceptions. The teacher needs to discover what the student is thinking to effectively work through these errors and add to the student’s knowledge base. “We have to do more than evaluate our students’ success. We have to listen and analyze what they are thinking and how they learn” (Redish, 2003, p. 8).

Creating a student-centered classroom does not just mean letting the students choose the path of learning haphazardly, which can happen if students are given complete freedom as in a discovery activity to “play” with the material provided and come
up with their own relationships with no assistance from the instructor. The instructor must act as a guide to provide purpose and provide students the room to make mistakes and learn from them as found in an exploration activity. The students are required to use conceptual information to solve problems introduced by the instructor (Redish, 2003). There is no set format that all groups will follow to get to an appropriate conclusion.

"Effective learning requires the students to be active participants in the process, not passive listeners" (Knight, 2004, p.5). The challenge faced by all teachers is how to get the students involved in their own learning. The use of computer-based laboratory systems in the classroom increases the active participation in the classroom by allowing students to set up their own equipment, collect and analyze data, and to make sense out of the data. Kennedy (2001) discusses a laboratory that a group of 7th grade girls developed and implemented to use the computer-based laboratory tools in her classroom. The girls set up a computer-based laboratory tool to count the number of times the refrigerator in the teacher’s lounge opened by using a light sensor hidden inside a brown bag lunch. After a normal day to obtain a baseline, they placed a plate of chocolates in the refrigerator with a note offering the treat free from the student council. The girls’ hypothesis was
that the number of door openings would increase if the refrigerator contained food that the teachers liked. The girls were very excited to see that the number of door openings nearly doubled. The conclusion was that teachers like chocolate. It also showed the girls that the computer-based laboratory tool could be used over an entire day when it would have been impractical for the girls to sit and count the door openings. With the computer-based laboratory tools the girls were engaged in scientific inquiry in conducting a relevant real-life investigation which improved their science reasoning skills.

**National Science Education Standards**

"Physics education research has brought out the need for instruction to be student-centered, explicitly recognizing the knowledge state of the students and the activities that will transform them to the desired state" (Knight, 2004, p. 41). In this paper, the focus is on the use of computer-based laboratory tools to facilitate a student-centered learning environment in a high school physics classroom. The technology alone will not impact the effectiveness of instruction on student learning. An inquiry-based physics classroom can allow students to utilize these tools with a focus on the students taking responsibility to plan and conduct their own investigations as well as analyzing their results and drawing their own conclusions based on evidence. In an inquiry-based physics classroom, the
The teacher’s role is one of a facilitator (Knight, 2004). Technology integration became a national science education initiative with the publication of the National Science Education Standards or NSES (National Research Council, 1996). The NSES provide recommendations on how science should be taught from kindergarten to grade 12 with the result of producing a scientifically literate society. The eight standards presented by the National Science Education Standards:

- Unifying Concepts and Processes;
- Science as Inquiry;
- Physical Science;
- Life Science;
- Earth and Space Science;
- Science and Technology;
- Science in Personal and Social Perspectives; and
- History and Nature of Science.

The three content standards relevant to the implementation of computer-based laboratory tools in the secondary physics classroom are science as inquiry, physical science and science and technology.

The science as inquiry content standard focuses on the science processing skills such as observation, inference and experimentation. The 9-12 grade students will realize science
is a process used to understand the phenomena around them. The concept standard develops how high school students think about science. The students at all levels are using thought processes to understand the natural world (National Research Council, 1996).

The physical science content standard refers to the concepts to be addressed in a secondary physics/physical science course. The topics addressed in physical science should include the "structure of the atom, structure and properties of matter, chemical reactions, motion and forces, conservation of energy and increase in disorder, and interactions of energy and matter" (National Research Council, 1996).

The science and technology standard promotes high-quality decision-making skills. Students observe the natural world with educational technology that can assist in the data collection and analysis. In activities, the students must identify the problem and work through a solution with technology acting as a tool. Learners then make decisions about the information that they observed in the laboratory (National Research Council, 1996).

**Computer-based laboratory tools in the classroom**

Computer-based laboratory tools became available to science teachers over twenty years ago, but have become more popular in our technological world. Nakhleh (1994) explains how the basic
CBL or MBL works. "Using a microcomputer to collect analog data about a physical system, to convert that data to digital input and then to transform that data into a graphical symbol system in approximately real time is an entirely appropriate use of the special capabilities of a computer and provides science educators with a powerful tool" (p. 368). Newer systems, such as the LabQuest and SPARK Learning System, use a digital signal, but have the same basic premise of transferring the data to a graphic form for analysis. The system itself does not answer the question of effectiveness in the classroom.

Computer-based laboratory tools are a way to integrate technology into the science classroom. A computer-based laboratory tool is a computer system that includes a group of sensors or probes, an interface, and data collection/analysis software connected to a computer that allows a user to collect, display and analyze physical data in real time. The systems have changed over the years. Microcomputer-Based Laboratories, MBLs, were the first types of interfaces that connected sensors to computers. Later, Calculator-Based Laboratories, or CBLs, that use graphing calculators instead of computers were introduced to allow for more mobility. As the computer became more mobile the systems have changed also. The newest technologies are all-in-one systems that are portable and allow data collection and analysis remotely without a computer.
connection. Vernier Technologies offers LabQuest interface which is an all-in-one interface for data collection/analysis with and without the computer, LabPro interface, which can connect to a computer or Palm handheld, and CBL 2 interface which connects to a graphing calculator. Each one of these can be used with the LoggerPro software for physical data collection and analysis (Vernier Technologies, 2008). PASCO offers SPARK Science Learning System which is an all-in-one; PASPORT which connects to computers and can take data to later connect to a computer; and Science Workshop which connects to a computer and can collect digital and analog data. These systems then use DataStudio for data analysis (PASCO, 2008). All of these systems require sensors which include motion detectors, force probes, accelerometers, thermometers, voltage meters, light probes and microphones. Use of this technology allows students to be actively engaged in scientific inquiry. The students collect physical data, validate the data and analyze the data, a process similar to that which a scientist utilizes.

**Inquiry-based vs. Cookbook Laboratories**

An instructor who desires effective integration of instructional technology into the physics/physical science classroom requires more than just using a computer-based laboratory system. A number of instructional resources are available for teachers to use to help with the integration of
instructional technology in their science classroom. These resources include activities that range from cookbook laboratories to inquiry-based laboratories.

A cookbook lab is just like a recipe that one must follow to produce the desired product. The materials and steps are provided and the learner only needs to follow the procedure to get the desired outcome. The learner makes no decisions and does not have the flexibility to make his or her own contributions to the learning experience.

In inquiry-based labs, the learner is presented with a problem or question to investigate in which evidence must be collected and analyzed to formulate conclusions. The experimental procedure is determined by the learner with limited guidance from the instructor.

Verification laboratories can fit into both lab types. If a student is only expected to follow a set procedure to prove a law or principle, the verification activity falls under the category of a cookbook laboratory. However, if the student is challenged to solve a problem that will validate the principle with control of the laboratory process, then the verification activity falls under the category of an inquiry-based laboratory.

The use of computer-based laboratory tools in a physics/physical science classroom does not guarantee that the
students will be learning in an inquiry-based instructional approach. A teacher can use computer-based laboratory tools and conduct cookbook laboratories. The tools are just the equipment. The curriculum and instruction that are used with the tools will determine the type of investigation that occurs and level of learning that will take place.

Summary

This chapter investigated the current trends in physics education for a more student-centered learning environment. Two types of learning cycles were discussed that can be used to teach in a student-centered classroom. The National Science Education Standards place an emphasis on the use of technology to increase student's conceptual understanding in science. The computer-based laboratory tools were introduced to create an active learning environment that is consistent with the recommendations of the National Science Education Standards.
Chapter III

RESEARCH FINDINGS

Introduction

Chapter three investigates the research about computer-based laboratory tools in the classroom. It begins with a table of research studies from the 1980s and 1990s. Then the benefits of computer-based laboratory tools in the classroom are investigated. Necessary steps for implementations are also discussed.

Research Findings

Research on the use of computer-based or calculator-based laboratory tools in the physical science classroom is sparse. Nakhleh (1994) created a table of early studies related to physical science. This table along with a summary of a study done by Beichner (1990) is found in Table 1.
Table 1 - Early research on CBL and MBL systems in the physical science classroom. (Nakhleh, 1994, p. 370-372)

<table>
<thead>
<tr>
<th>Researchers</th>
<th>Purpose of Study</th>
<th>Contribution of Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Adams &amp; Shrum, 1990</td>
<td>Secondary students understanding of graphs.</td>
<td>No significant differences between MBL and control students in cognitive level, graph interpretation, or graph construction. MBL students came to regard the computer as a useful tool.</td>
</tr>
<tr>
<td>2. Wiser &amp; Kipman, 1988; Wiser, Grosslight, &amp; Unger, 1989</td>
<td>Secondary students' heat and temperature concepts.</td>
<td>Students improved their ability to differentiate between heat &amp; temperature using a combination of MBL and computer models.</td>
</tr>
<tr>
<td>3. Beichner, 1990</td>
<td>Secondary and college physics students' understanding of kinematics via demonstration and computer simulations as compared to MBL.</td>
<td>Compared to other studies using MBL, the students did not achieve as well as MBL students. Results suggested that direct personal control of the computer and/or kinesthetic experience of producing the graph produced the enhanced MBL learning.</td>
</tr>
<tr>
<td>4. Brasell, 1987</td>
<td>Secondary physics students' interpretation of real time or delay time motion graphs.</td>
<td>Students using real time MBL demonstrated enhanced understanding of motion graphs. Delayed motion graphs did not enhance their understanding of motion graphs to the same extent.</td>
</tr>
<tr>
<td>5. Powers &amp; Salamon, 1988</td>
<td>Described an MBL implementation in a Missouri high school.</td>
<td>Both control and experiment students increased their score on a Scientific Aptitude Inventory, a Science Skills Assessment and a Computer Literacy Assessment. No tests of significance were reported. Teachers reported an increase in their computer literacy.</td>
</tr>
</tbody>
</table>

Overall, the studies have shown little correlation between MBL/CBL use and conceptual understanding or science inquiry proficiency. Students show a gain in technological literacy, but no pronounced change occurred to their conceptual understanding or science inquiry skills. If there is no gain in student conceptual understanding or science reasoning, why are computer-based laboratory systems gaining more popularity? The research supported a number of benefits to the use of computer-based laboratory systems in the secondary physics
The benefits include:

- Data Collection
- Genuine Scientific Experience
- Graph Production
- Different Learning Styles
- Motivation
- Conceptual Understanding

Computer-based laboratory systems can affect data collection in a variety of ways (Marcum-Dietrich & Ford, 2003; Trumper & Gelbman, 2001; Nakhleh, 1994; Kulik, 2002; Kwon, 2002; Christmann, 2004; Sterling, 1998; Hale, 2000; Poole, 2000). The first is the speed of data collection. The computer-based laboratory system allows students to take data more quickly than with traditional lab equipment. This quickness allows students to verify results through repeated trials (Marcum-Dietrich & Ford, 2003). Multiple trials allow a shift on the student’s part. More time can be used on evaluation and analysis of data, rather than data collection alone. This shifts the focus to
critical thinking, problem solving and self-monitoring progress (Krajčík & Layman, 2005).

Along with reducing the amount of time to collect multiple trials, computer-based laboratory tools also allow data collection with relative ease that can be difficult and/or expensive to collect with conventional instruments. Students can act as scientists as never before. The computer-based laboratory tools can even collect and analyze a number of sets of data at the same time. Multiple sources of data for a moving object in the physics laboratory can be collected from a motion detector and a force probe connected to the computer interface at the same time. These probes used at the same time allow the students to investigate a number of variables such as position, velocity, acceleration and force concurrently for a moving object. The corresponding motion and force graphs can give a large amount of information in various visual representations in which students must determine the relationships between variables.

Students are also able to manipulate the data into multiple representations with only a few keystrokes or clicks of the computer mouse. The students can change from one motion graph like a position versus time graph to another such as velocity versus time graph with only a click of the mouse. Students can very easily and quickly analyze the motion graph by determining
the slope, the line of best fit, and the area under the curve with a few clicks of the mouse. In the past, these processes would have taken more effort and time to complete. The students would have had to take additional data, make the necessary calculations and possibly construct two or more graphs to make the same comparison and do the same type of analysis. Graph 1 illustrates position vs. time, velocity vs. time, and acceleration vs. time graphs collected with a motion detector, Lab Pro interface, and LoggerPro3 software for a dynamics cart traveling down an inclined track.

Graph 1: Motion graphs exported from LoggerPro 3 (Vernier, 2008).

Trumper and Gelbman (2001) investigated data collection and noted that computer-based laboratory tools increased the accuracy of lab results. Students will be able to make better measurements of physical quantities like the acceleration due to gravity. With less technologically advanced equipment, data
collection can be a more difficult undertaking involving more calculations. Generally the mathematics involved muddles the science behind the concept. The students can also see errors or fluctuations in their data during collection so time is not spent on analyzing bad data points but on refining their lab procedures in order to reduce these errors or fluctuations.

Another benefit of computer-based laboratory tools is the ability to collect and analyze data in real time. The real time data collect and graph production allows the student to focus on the data analysis rather than graph production. The MBL does not teach concepts, but rather frees up students' thinking for making meaning out of the experiment (Nakhleh, 1994). The MBL or CBL can also save this data for later if time is short.

The immediacy of graph production aids students in making connections between the data and the phenomena observed in the laboratory (Marcum-Dietrich & Ford, 2003; Krajcik & Layman, 2005). Students see more connections between graphs and actual events. As discussed previously, Kennedy (2001) confirmed this result. The middle school students were able to show the kindergarten and first grade students how their motion was related on a motion graph.

Kulik (2002) states MBL give students a "genuine scientific experience." (p. 6) (Lapp & Cyprus, 2000; Trumper & Gelbman, 2001; Weller, 1996; Huetinck, 1992). Students are able to ask
the questions and then use the tools available to solve them. In turn, the role of the student changes from inactive to actively creating a student-centered learning environment. The MBL and CBL allow students to explore the real world as never before. The classroom is no longer the only place for learning to occur. The students can take the computer-based laboratory tools and collect data anywhere.

Science is not only a group of facts to be learned. Instead, it is a process by one can make evidence-based conclusions that can be tested. The learner needs to be involved in the process to be the "scientist." A shift from traditional lecture methods of teaching science where students are passively sitting with very little interaction is being made to student-centered methods where students are becoming more involved in the pursuit of new knowledge (Knight, 2004). Students can use computer-based laboratory tools as a means for gaining conceptual understanding.

Hale (2000) found "an emphasis on conceptual opposed to procedural learning - on understanding the ideas as opposed to knowing how to do the procedure" (p. 416). The student can use the MBL or CBL to collect and analyze data allowing more time for understanding. Students can change procedures and see where errors are happening as the data is being recorded rather than waiting for analysis, sometimes days later. The students are
allowed to use the data to guide their research similar to what a scientist does on the job.

Students can use and collect data about real-world problems. Through real-world problems, the students are able to learn a number of scientific concepts. The ability to change location and subject matter can also increase motivation and relevance for the students. Sterling (1998) refers to a science curriculum unit about stream quality. The students can develop a number of questions from a visit to a local stream, depending on the intended result. The teacher would have to decide some basic parameters of what the intended results will be. The curriculum unit could last a week or the full year depending on the various data sets they collect, graph, and analyze.

Possible data collection may include air and water temperature, pH, and dissolved oxygen. The students could also test for contaminants in the water to check for water quality.

A common theme among researchers is the reduction of the drudgery of graph production (Trumper & Gelbman, 2001; Kulik, 2002; Nakhleh, 1994; Huetinck, 1992, Poole, 2000; Lapp & Cyprus, 2000; Weller, 1996; Krajcik & Layman, 2005; Sillman, Zembal-Saul & Dana, 2000; Kwon, 2002; Knight, 2004). Huetinck (1992) explored the reason for the drudgery of graph production, "the tedium of the act of graphing - determining a scale, labeling axes and plotting points - can detract from attaining an
Students spend time on constructing the graph, but struggle to find meaning in the data represented. Lapp and Cyrus (2000) discuss how graphing experience changes thinking.

"Brunnfer (1966) suggests a progression from inactive to iconic to symbolic representations, that is, the students move from physically modeling the problem with materials (inactive) to diagramming or graphing (iconic) to putting the problem into an abstract mathematical form (symbolic)" (p. 507).

The students can bridge the gap between physically observing the phenomena and putting it into a more abstract mathematical relationship. "...Real time display of graphs, as the data is being collected, allows students to associate the shape of the graph with the behavior of the object" (Knight, 2004, p. 53). This ability is essential to excel in the sciences. The graph needs to have meaning for the learner in order for it to be useful.

Graphs are an integral part of science and science education. "The principal goal of the laboratory activities is to lead students to develop a conceptual correspondence between targeted aspects of the real-world phenomenon and corresponding symbolic representations" (Modeling Instruction Program, 2008). The computer-based laboratory tools analyze data immediately allowing students an excellent opportunity to connect graphs to
the physical phenomena being observed (Krajcik & Layman, 2005).

Weller (1996) states “Many students increased their graph repertoire (especially adding line graphs to their options for representing data) and sophistication of interpreting graphical representations” (p. 470). Learners make connections from the laboratory experience to the interpretation of the data collected. With traditional lab equipment, the time between data collection and analysis could be days. The use of computer-based laboratory tools makes the process instantaneous.

Sillman, Zumbal-Saul and Dana (2000) discussed a relationship between the computer generated graphs and the understanding of the concepts by the students. Students can make connections to the concept when there is no delay in the analysis. Delay between the phenomena and analysis does not allow students to make concrete connections. Scientific thought demands that the concept be supported by data. Students do not have the ability to make the connection without immediate feedback.

Students learn in a variety of ways. These different learning styles are hard to reach with every lesson. Computer-based laboratory tools allow students to learn in ways appropriate to a variety of learning styles (Weller, 1996). The available variety of representations of the physical data and the necessary interactions with the computer-based laboratory
tools allow students to use what works for them. Visual learners can make connections with the graphing of the information. Hands-on learners are able to manipulate the equipment in the lab and make changes physically with the graphs.

Spatial and mathematical reasoning are improved by the use of this equipment. Students are able to make connections with the physical phenomena and the graphical representation of those phenomena. "The computer integrates the real world with associated mathematical representations in a unique experience that offers much beyond the traditional method of teaching graphing" (Huetinck, 1991, p. 100).

Kennedy (2001) describes a partnership between kids and computers. The sensors and probes allow students to explore a number of phenomena around them. The students can use the computers in their lab experiments which is a motivation because they find computers fun.

Nakhleh (1994) discusses a connection between developing graphs and motivating students in the classroom. The students find the computer to be trustworthy partner which allows them to concentrate on other tasks. The computer can collect data and the students can manipulate it with little effort. The students enjoy the experience. The students don’t get bogged down with the tedium of graph production, as discussed earlier.
"Using science probes in the classroom is an exciting way to integrate technology with inquiry-based science" (Sterling, 1998, p. 51). The classroom can be much more students centered. Learning is retained better in an inquiry-based classroom (Knight, 2004). Students are able to internalize the experience.

"MBL appears to be a powerful motivator and learning tool, but it is up to the instructor and students to use it wisely" (Nakhleh, 1994, p. 379). Students enjoy technology, but need to see it more as a tool than a toy. Computer-based laboratory tools can be a powerful when integrated into the science curriculum correctly. The goal is to educate the students about the scientific content. The technology is only a small part of that final goal.

"Comparison with conventional instructions shows that MBLs are highly effective for teaching a conceptual understanding of motion and force" (Knight, 2004, p. 53). Knight (2004) points out that it is not the computer-based laboratory tools alone, but rather the teaching method used in the classroom. Students need to be guided to the correct phenomena to study with the right questions being addressed.

These six points show how important computer-based laboratory tools can be in the teaching of science. These tools are helping students learn important skills, but they are only
tools. The technology alone will not improve science ability which was shown in the early studies.

Components needed for implementation

The research showed three essential components necessary for implementation of computer-based laboratory tools into the classroom.

• Classroom environment
• Professional development for teachers
• Funding

"Students must be guided to study the appropriate phenomena and asked the right questions about what they’ve measured with the computer" (Knight, 2004, p. 53). The student-centered classroom is not just a random environment. The teacher must guide the students to construct their own knowledge and/or understanding.

"MBL tools by themselves will not develop an environment that will allow students to explore concepts" (Krajcik & Layman, 2005, p. 5). The equipment helps facilitate labs and inquiry only when used as a tool. Computer-based laboratory tools alone cannot create an effective learning environment in a science classroom. Teachers need to use these tools with their existing curriculum to assist students in learning. The traditional teaching approach must change for integration of computer-based laboratory tools to be successful. Teachers must turn over some
to the learner.

The second piece is the professional development of teachers (Sillman, Zembal-Saul & Dana, 2000). The teacher is the person who creates the learning environment of a classroom. If the teacher is unsure of the technology or concept, the students will also have difficulty. Many practicing teachers have never received professional development on how to use the instructional technologies and how to implement them into their classrooms. Many professional development opportunities for teachers have little or no follow through. The information is presented in workshop and then the teachers are not supported in their implementation. Teachers need to have opportunities to be shown how the technologies work and provided information on how to use them. Teachers also need to model how these technologies can be implemented and integrated into their classroom. They also need to be provided with support and follow-up professional development as they implement these technologies in their classrooms.

Area Education Agency 267 in the state of Iowa, in collaboration with the University of Northern Iowa Physics Department, is tackling this problem with an initiative through participating local Area Education Agencies. Starting in the summer of 2006, secondary physical science and physics teachers
were invited to be involved in a program called Enhancing Education Through Technology (E2T2) - Science Initiative for High Schools. Participating teachers received computer-based laboratory tools, curriculum materials, and other equipment as well as graduate credit from the University of Northern Iowa. They were provided professional development and support in the use and integration and implementation of these resources in their classrooms consistent with the recommendations of both state and national science education initiatives.

The participating teachers were required to collect and report student assessment data to guide their instruction and provide insight on the effectiveness of their implementation. The teachers were also required to attend academic year meetings and participate in professional conferences and two intensive week-long summer workshops. The E2T2 program is a good example of how physics/physical science teachers can be provided the instructional resources and support to integrate and implement computer-based laboratory tools in an inquiry-based classroom.

The instructional curricula utilized in the E2T2 program included Physics Resources and Instructional Strategies for Motivating Students (PRISMS) PLUS (Cooney, Escalada, & Unruh, 2005) and Modeling Instruction (Modeling Instruction Program, 2008). Both curricula utilize modified learning cycle pedagogy.

PRISMS Plus is a high school physics curriculum divided
into 4 units including:

1) Force and Motion,
2) Work and Energy,
3) Waves and Optics and
4) Electricity, Magnetism & Modern Physics.

These units allow the instructor to pick and choose what units and topics he or she wants to introduce in the classroom. In a typical classroom, teachers would be unable to address all four units in a year-long physics class. Each unit contains a number of complete learning cycles or sets of activities. Each learning cycle contains an exploration, conceptual development and application activities. Materials are also available to provide students with conceptual support as they develop and reinforce their understanding of the concepts being introduced.

Modeling Instruction is a physics curriculum developed at Arizona State University (Modeling Instruction Program, 2008). This program uses a modified learning cycle referred to as the modeling cycle. There are two distinct parts of this cycle. Modeling development includes the exploration and concept development of the learning cycle. Modeling deployment uses the new information to apply it to new situations. The computer-based laboratory tools are used to collect and analyze physical data. The teacher is a facilitator during the entire process and uses a Socratic questioning style to push the students
toward the intended goal. It is not complete discovery learning because the teachers identify expected outcomes for each modeling cycle (Modeling Instruction Program, 2008).

Funding is the last component. Computer-based laboratory equipment can be expensive (Poole, 2000, p. 209). Area Education Agencies and universities can be wonderful resources for help with funding or to borrow equipment to use for a week or longer. For example, the UNI Physics Department has a Carver-funded instructional technology loan program for Iowa science teachers who participate in UNI physics and science education professional development programs. This program provides participating teachers and schools with computer-based laboratory tools and other resources on loan to implement interactive engagement techniques in their classrooms. As a result of having access to these tools and resources, teachers and schools are stimulated to obtain these resources for themselves by seeking funding.

**Resources for computer-based laboratory tools**

The resources available to teachers also affect implementation of CBL and MBL technology in the classroom. A number of resources exist and are available for teachers. However, they are not all appropriate for an inquiry based classroom. Some of these resources include materials like those found in my own classroom. For example, Glencoe Publishing has
lab resources available to complement their textbooks (Zitzewitz et al., 2005). The students are asked to use CBL systems for these activities. These labs are very cookbook in nature. The authors give step by step procedures that will get to the right answer. Students are not responsible for any of development of the procedure.

Another readily available option is the science curricula resources developed and distributed by Vernier Software and Technology - a vendor for calculator-based and computer-based laboratory tools and resources. The science curricula books provide 20-25 activities in the disciplines of biology, chemistry, physics and physical science with the emphasis on using calculator- or computer-based laboratory tools (Vernier, 2008). Although these books provide excellent instructions for the students to set up the equipment, they unfortunately are very cookbook in nature. Directions are step by step and tell students exactly what buttons to push when. This is very helpful for students who have never been exposed to the technology before, but is not designed to be used in an inquiry-based classroom.

Both PRISMS PLUS and Modeling Instruction implement computer-based laboratory tools integrated with easily accessible, everyday materials (PRISMS PLUS especially) within their curricula. Computer-based laboratory tools are used by
the students to collect and analyze physical data. The laboratories do not include step by step instructions like that given in the other resources. The students are introduced to the system at the beginning of the year and work to better understand what the system can do. The individual activities allow the students to look for relationships and develop equations to support the physics concepts covered.

**Summary**

This chapter explored how computer-based laboratories can be used to improve instruction in the high school physics classroom. Early research shows little or correlation between the use of computer-based laboratory tools and science test scores. However, more recent research contains a number of benefits to support the use of computer-based laboratory in the high school classroom. The benefits include data collection, genuine scientific experience, graph production, different learning styles, motivation and conceptual understanding.

Teachers also need to have resources to make these implementations into the classroom. They include classroom environment, professional development and funding. The last section of the chapter identifies some of the resources available to the classroom teacher to assist in implementing computer-based laboratory tools.
Chapter IV

ANALYSIS AND IMPLEMENTATION

Introduction

The research question for this paper addresses the integration of computer-based laboratory tools in the high school physics classroom. Early research shows no direct correlation between science scores and the use of the technology in the classroom. A change in the way physics is taught is necessary for the best results.

Computer-based laboratory tools open a number of avenues for teachers and students. Real science learning can happen in the classroom. Students are able to collect and analyze real-time data. The early research on CBLs and MBLs in the classroom found little or no correlation between science scores and their use in the classroom. However, significant improvement in the scores on the FCI was found within more student-centered classrooms. Richard Hake found that active learning classes scored twice the gain of conventional instruction on the FCI (Knight, 2004):  

Physics education researchers are learning more about how students learn physics. Students need to have an active role in their learning. The information needs to be internalized in order for this to occur. The computer-based laboratory tools
are a resource that can assist in data collect and analysis.

**Personal Insight of Benefits of Computer-Based Laboratory Tools in the High School Physics Classroom**

Researchers found six ways that computer-based laboratory tools are beneficial when used in the physics classroom. They include:

- Data Collection
- Genuine Scientific Experience
- Graph Production
- Different Learning Styles
- Motivation
- Conceptual Understanding

Each of these benefits has merit in the high school physics classroom. I will discuss my insight into how they affect my classroom.

Computer-based laboratory tools are used for data collection. They allow for much faster and accurate physical data collection. The students are able to "paint" the graph of motion as it is occurring. The students can see what is happening as it happens so that they can make changes as necessary. A traditional laboratory to study an object in motion can take 2-3 days in a 42 minute class period. The students would be responsible for collecting data and then
graphing data. If multiple representations were necessary it could take even longer. The computer can do those things for the students so that they can think about the phenomena they are observing. Connections are made between the data and the physical phenomena instantaneously.

The computer-based laboratory tools allow students to have a genuine scientific experience that is both rigorous and relevant. The Iowa Department of Education has two current initiatives that stress the rigor and relevance in the high school curriculum. The first is R4, which stands for rigor, relevance, relationships and reflection (Rigor and Relevance, 2008). The purpose of this initiative is to require teachers to make curriculum relevant to learners in the 21st century. The way for students to better understand is to provide a student-centered classroom where the teacher facilitates learning. The computer-based laboratory tools make the physics content more relevant to the world around them. The students are able to collect and analyze data for experiments that were difficult or impossible in the past.

The second initiative is the Iowa Core Curriculum which was recently approved and mandated by the Iowa Legislature. This is an entire curriculum that provides the standards for all students in Grades K-12 (Iowa Core Curriculum, 2008). The Iowa Core Curriculum includes standards about math, literacy,
science, social studies and 21st century skills. Individual school districts must decide how they will address these standards. This allows teachers in these schools to still have control of the content being introduced in the classroom. The integration of computer-based laboratory tools and interactive engagement techniques with a focus on science inquiry are consistent with the recommendations of the Iowa Core Curriculum related to secondary science and 21st century technology skills.

I believe the biggest benefit of the computer-based laboratory tools is the graph production. It allows students a lot more time for analysis. Many students struggle with the process of making a scale and graphing a data set. Although that is an important skill that I still teach, it is only part of the entire picture. With the computer-based laboratory tools, students are able to see graphs as they happen. The time for analysis is cut down and more labs are able to be completed.

In the inquiry-based classroom students are expected to make relationships between variables. The old method would have been to graph multiple representations of the data. With the use of the computer, students can manipulate the variable and change the graph with a click of the mouse. Students can then use more of their concentration on developing and reinforcing their understanding of the concepts rather than the drudgery of graph production alone.
Students are individuals. They all learn in a different style. I’ve noticed that the computer-based laboratory tools allow for these differences. The graphing experience is only part of the laboratory experience. Students work in cooperative groups in the laboratory which allows interpersonal skills to be enhanced as well.

Our society is one that embraces new technologies. The students have a number of gadgets that make life much different than it was just a few short years ago. The computer-based laboratory tools in the classroom are a motivator. The students enjoy the new technology. My students love to come in to the classroom when the computers are available for them to use. They are always disappointed if it was for the class before them and not for them. The computer is a trusted laboratory partner that helps with the mundane parts of the lab.

The final benefit is the conceptual understanding. This understanding can be achieved without the computer-based laboratory tools. The students can come to understand the basic ideas of physics and other phenomena introduced in the high school physics classroom without using computer-based laboratory tools. But, I believe the computer makes a difference because it can do the graphing and generate the line of best fit allowing the students to analyze the information in more detail. The students can see the relationship between the motion of an
object and the resulting graphs produced. When the student gets muddled in the basic graph construction and analysis on the graphs, there is less time for the conceptual understanding to occur.

The students used the computer-based laboratory tools as a tool not as a stand in for good teaching practices (Redish, 2003): Computer-based laboratory tools are not a curriculum. They are a tool to improve student data collection and analysis. Teachers still need to use care to foster a classroom of inquiry.

Teachers need to use these tools in the classroom to allow the students to explore the world around them. The students can discover the relationships between variables by analyzing their data. The amount of information that can be collected is phenomenal and the analysis is instantaneous. In the past, these activities may have been skipped because of the time factor: Students would have to collect data, graph data and then analyze data. The computer can do the collecting and graphing which leaves the students more time for interpretation.

Many resources are available for the teacher for curriculum ideas. There are a number of resources available online and through textbook companies. The companies that make the equipment themselves also sell manuals to use the sensors. Although they provide useful information on how to set up the
equipment, I’ve unfortunately found that most of the resources are very cookbook. I’ve used the cookbook labs to introduce the use of the technology, but strayed from them once the students are comfortable with the technology. More open ended activities have shown to be more effective in developing proficiency in scientific inquiry. Students can use the sensors to take any type of data, and that makes them very user friendly.

**Teachers Role in Integration of Computer-Based Laboratory Tools**

Students learn better in a student-centered environment so the technology is only part of the improvements needed in the science classroom. Teachers need to participate in professional development opportunities and be provided support in order for them to make changes to their teaching styles. A difference in pedagogy will be more helpful than simply bringing in new instructional technology like computer-based laboratory tools in the classroom. Both pedagogy and the instructional technology need to be integrated. Teachers need instruction on how to integrate the instructional technology to facilitate scientific inquiry. They need assistance on how to ask the right questions at the right times for students to be mentally engaged in making sense of the physical data being collected by the computer-based laboratory tools.

The E2T2 program assisted me with the implementation of the
computer-based laboratory tools into my classroom. The focus of the program was on the interactive engagement techniques found in the PRISMS PLUS and Modeling Instruction curricula, not the technology itself. I found this to be a wonderful way to integrate technology in the science classroom. I am however, computer sophisticated but not all teachers who are not comfortable in using technology were happy about that approach. The technology was not the highlight of the program, but rather an added bonus.

Teacher and students need to create a partnership in the classroom. The teachers must act as facilitators in the classroom. There is always an intended outcome. The way that each student gets there will not be identical, but that is where individualization occurs. Student questions can lead the explorations and then concept development can introduce the new concepts needed to understand the root of the questions. Students take the role of scientists, allowing the learning to be internalized, and they will take the information farther than the test on Friday.

Funding for the technology can come from a number of sources. A number of grants are available to teachers if they do a little research. The community members you teach can also be a wonderful resource. The biology teacher in my district wrote a letter to the editor for the local paper.
requesting funding for a digital microscope and some sensors for his classroom. The community raised about eight hundred dollars which he used to purchase the needed equipment. These people are the future employers of your students and want them to be well prepared for the future. Parents can also be a resource because they want the best for their children and understand that funding for education is not stretching as far as it did in the past.

Computer-based laboratory tools are a wonderful tool and this generation of students is tuned into technology more than any generation before it. Students have access to technology in all parts of their lives. They have iPods, computers, and cellular telephones. Bringing the instructional technology into the classroom can be a motivator to learn science too.

The teacher needs to understand the basics of the computer-based laboratory tools for successful implementation in the classroom. Professional development, such as the E2T2 program mentioned earlier, allows the teacher to act as a student and experiment with the technology in a hands-on manner with experts looking on. This program has also allowed me to make peer contacts to assist me when I was unsure about this new technology. The E2T2 program met during the school year and allowed teachers time to share successes and failures in the classroom. The teachers were one of the best resources because
they were all in it together. We were all trying to improve our classroom by using an inquiry-based classroom style to implement the computer-based laboratory tools.

In order for any of this new technology to effectively integrate into the high school physics classroom, an environment of trust is essential. Students and teachers need to create a partnership that allows questions to be asked and answered together. No question can be deemed unworthy of your attention. The students can help each other to understand what is happening in the laboratory experience. The Modeling Instruction program provides opportunities for students to white board their procedures, analysis, and conclusions of their experiments to share with each other and to engage in Socratic Dialogue with their peers and instructor. This can be done in any science classroom. The sharing allows the students to see different points of view or different variables that are being studied at the same time. It was a good way for the students to assist each other with the learning of the concept being studied.

The various topics of a physics curriculum also affect the amount of use the computer-based laboratory tools get in the classroom. The topics of motion and force can incorporate a number of experiments that utilize computer-based laboratory tools. These are topics where I use the equipment a great deal. The topics of waves and sound have fewer available sensors.
Therefore, these topics do not utilize the computer-based laboratory tools, but rather use other laboratory tools. The topics of interference, diffraction and reflection of waves are best demonstrated with a ripple tank and/or computer simulations. So the computer-based laboratory tools will not replace all the labs that can be done in a normal high school physics classroom.

Computer-based laboratory tools have added a new dimension to my classroom. Students are able to take data as never before. There instantaneous graphing allows students to see mistakes and make changes as they go. This is more like an actual scientist. The students are also able to find relationships between different variables with ease.

**Summary**

Overall, computer-based laboratory tools are wonderful tools for the classroom. It is only a tool, not a replacement for good teaching. The classroom needs to change for this equipment to be more effective. Students need to be the center of the classroom, which is a tough thing for some teachers to do. We tend to teach the way we were taught. The current generation does not succeed in a bland lecture based classroom. Students need to be provided opportunities to act like scientists where they themselves identify problems to be investigated, formulate predictions and procedures to carry out,
analyze their data, and formulate conclusions. Society is in need of science sophisticated students who can increase our understanding of the science and technology of today and tomorrow.
Chapter V

CONCLUSION AND IMPLICATIONS FOR PRACTICE

Introduction

Chapter five summarizes the implications for practice and conclusion. The teacher needs to change how he/she teaches in order to implementation of computer-based laboratory tools to impact student learning. The technology alone is not enough, but rather a change in the way science is taught in the classroom must happen too.

Implications for Practice

Computer-based laboratory tools open avenues that were previously unexplored in the high school physics classroom. Students can take data and analyze results like never before. The teacher can bring real world experiences right into the classroom. The research, however, does not support or disprove the advantages of using this technology in the classroom. The researchers found a number of reasons that computer-based laboratory tools are an excellent addition to the science classroom.

Students can take real time data about real world problems. They can also analyze that data with the computer or calculator that collects the data. Taking away the drudgery of graphing also allows more time to be spent on the concept of the lesson
instead of making a graph with a good scale.

The computer-based laboratory tools can be implemented in the classroom to increase both rigor and relevance in ways that are consistent with both state and national science education initiatives. The computers can assist with the data analysis. This can allow for analysis that would be mathematically difficult in the past.

The portability of the system also allows them to be used in a number of environments. This allows the students to study phenomena outside the classroom, which adds relevance to the science topics being studied. Students are no longer fenced into the school building. Science happens everywhere and these sensors can be mobile enough to study wherever that science is found.

Teachers need to be instructed and modeled how to teach with a more student-centered focus for computer-based laboratory tools to be the most effective. The cookbook labs teach reading and following directions, but not the science concepts. Students need to take the initiative to assign the variables and make observations. Then they can make changes as they go along and real learning is taking place. Students who are spoon fed the information will not understand and won’t remember past the test.

The E2T2 program was a wonderful way to be introduced to
the technology and receive professional development in physics/physical science. Teachers were shown how to integrate the use of the technology with interactive-engagement techniques by acting as the students during the activities and then interpreting the teaching approach together afterwards.

In addition, teachers need to be allowed to use the technology in a number of different situations to feel comfortable with the new technology. The main component after training is the time it takes to prepare, implement, and practice using these new approaches. The classroom environment also needs to change, which can be challenging for teachers. I'm still struggling with the transition to an inquiry-based classroom. Giving the control to the students is essential, but also difficult. I find myself challenged in making my classroom completely student-centered because of this issue. I want the students to learn and grow, but I tend to teach how I was taught too often. The time needed to implement a totally student-centered classroom is much more than a traditional lecture based classroom. The students can ask many questions and a teacher needs to be prepared to address these questions and guide their learning.

Conclusion

Computer-based laboratory tools can be used to fulfill the requirements of the Iowa Core Curriculum. The student skills
and proficiencies identified in this initiative can be met in a number of ways. Individual districts choose how each standard is met and in which classroom. Computer-based laboratory tools increase students' technology skills as well as science skills. Future researchers must continue to study how the learner learns the concepts in the physics curriculum. The computer-based laboratory tools need to be used as tools, not as a stand-alone component to the classroom. The conceptual assessments, such as the TUG-K and FCI, are necessary to gauge the effect of new teaching techniques with the older standards. I have used the TUG-K and FCI since I was involved in the E2T2 program. Both assessments in the form of pretest and posttest comparisons show that my students are making progress towards more conceptual understanding. I, however, don't have data from before I made changes to my classroom to make any comparisons with how I am now teaching with how I taught previously. A student-centered approach needs to become the norm in the high school classroom.

Overall, I believe that computer-based laboratory tools are a wonderful addition to my classroom. The students enjoy the autonomy from me during lab and I enjoy the discovery that was lacking. Students take ownership in the experiences in the classroom and real learning seems to be happening. I will continue to use the sensors and interfaces in my classroom to
allow students the real world experience of science.

Summary

Teachers need to make changes to the way that they teach in order for computer-based laboratory tools to make a difference in the student performance. This chapter shared my personal insight into the implementation of computer-based laboratory tools in my classroom. My students are showing gain on the TUG-K and FCI assessments in the form of pretests and posttests, but I'm not sure how students taught in with my current instructional methods and resources compares with students taught with my previous instructional methods and resources because of a lack of previous data.
References


