This is to certify that the

thesis entitled

Using Multimedia Technology in Chemistry
Pre-Laboratory Preparation

presented by

Jeffrey Glen Yoder

has been accepted towards fulfillment
of the requirements for

Masters of Science degree in Interdisplinary
Physical Science

Major professor

Date 22 July 02

USING MULTIMEDIA TECHNOLOGY IN CHEMISTRY PRE-LABORATORY PREPARATION

By

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A THESIS

Submitted To
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Natural Sciences

2002

ABSTRACT

USING MULTIMEDIA TECHNOLOGY IN CHEMISTRY
PRE-LABORATORY PREPARATION

By

Jeffrey G. Yoder

This study investigated whether the use of multi-media technology (including the use of internet links, video and audio clips, computer graphics & pictures, and text information) would improve student understanding and performance on laboratory experiments. Over the course of study it was determined based on student pre-lab scores, actual student time spent in lab, and instructor observations that students showed improvement in understanding of lab objectives, safety information, laboratory techniques, lab efficiency, and practical applications. Post-lab write-ups, extensions, and overall results showed no significant change.

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Introduction

This investigation is primarily concerned with the following question: Does using multi-media technology in laboratory preparation improve student performance on laboratory exercises with regards to lab efficiency, technique, and understanding of underlying concepts? This main question is broken down into three areas: (1) Do students better understand (compared to other lab preparation methods) the overall lab objectives, equipment identification, and safety information of a particular lab? (2) Do students perform better in the actual mechanics of the lab? (3) Do students perform better on the post-lab report and related calculations involved in the lab?

Background & Pedagogy of Technology

Before undertaking the actual study it was important to find out what pedagogical support existed for this idea of using technology and computers as a tool for classroom learning. The use of computers in education dates back to the1957 launch of Sputnik by the Soviets, which caused the American education system to begin major reforms in educating its students (Withrow, 1997). Initially the first computers were nothing more than simple number crunchers. As such, their primary use was in mathematical problems, such as calculating pi to many decimal places. Since these first computers were large, expensive, and difficult to maintain they were confined to the math, engineering, and physics departments of larger universities (Molnar, 1997).

The major breakthrough in using computers for education came in the 1970s with the introduction of the personal computer. As a "child of the '80s" I can recall the very first computer lab that we had in our high school: about twenty Apple computers with three-color monitors. Even the relatively simple computer simulations, mostly text based at the time, allowed each of us to explore concepts and topics that could not easily be represented on paper. This included a nuclear power plant and graphing complex algebraic functions by entering the equation and letting the computer do the calculating and plotting (instead of doing all the tedious graphing by hand). This gave me and my peers the opportunity to more easily investigate and manipulate variables in order to see how the rules of math "behaved". The goal was to understand how things worked rather than to merely crunch numbers and produce a graph.

At this point many still viewed the computer as useful for mostly simple drill-and-practice types of learning (Withrow, 1997). I can recall simple multiple-choice types of practice programs in which a correct answer to one question allowed the learner to progress to a more difficult problem while a wrong answer would bring up another problem similar to the incorrectly answered problem. Even this simple method opened up the possibility of learning based on the abilities of the individual.

Although today's computers far outpace what I dealt with as a teen-ager, the question of how to effectively use these computers is still a source of debate. Successful approaches vary from hands-on experiments with actual objects to text-based messages, depending on the sophistication of the learner (Molnar, 1997):

> *"For example, to describe a worm to a preschooler may require a trip to the garden to dig up a worm; by school age, however, a good picture of the worm is enough; and, in a high school biology lab, black-and-white lines may easily define the worm for the student. The more sophisticated the learner, the more stylized the symbol can be. Illustrations, photographs and audio segments need*

not be online for more sophisticated learners. Thus, rather low-cost computers can provide a wide range of online text-based education for sophisticated learners." (Molnar, 1997)

The technology that we currently have in our computer lab certainly supports the graphic and audio requirements for the pre-lab activities I am proposing to use. In addition, the level of sophistication of my students should match with the level at which the information would be presented to them.

Computers seem particularly useful in helping learners visualize what would otherwise be a long written description or idea (Molnar, 1997). The phrase "a picture is worth a thousand words" may come to mind at this point. A recent study (Molnar, 1997) suggested that computer graphics and related tools allow the mind to restructure a problem into a more perceptual system and free up other areas to allow the student to have a better understanding of the ideas behind what is being shown. I found this aspect of using computers to have been very helpful in providing some guidance as to how to use technology in my study. What would take me an entire page of written information to convey (such as safety or "tricks and tips" regarding lab techniques) could be shown with a minute-long (or shorter) video and audio clip from which the student's visual memory could more easily access the information.

A number of other studies support the idea of using technology in a variety of different instructional methods (Kulik, 1991, Andersen, 1993, Wenglinsky, 1998, & Wilcox, 2002). Analysis of several hundred studies showed that computer-based instruction could increase student's scores while reducing the time necessary to achieve those scores, even to the point of being comparable to peer tutoring (Kulik, 1991). In another study the use of computer-based "tutors" resulted in letter-grade improvements for students in math and computer programming classes (Anderson, 1993). Using computers to help with higher-order concepts was also found to result in significant gains in student learning (Wenglinsky, 1998). A very recent report indicated that middle school students showed great improvement in standardized math and language arts tests after using computer software designed to give them individualized instruction with the instructor acting in a less traditional facilitator mode (Wilcox, 2002).

Some studies (Wenglinsky, 1998, Schenone-Stevens, 1999, & Moss, 2000) do point out at least two major areas of caution: the instructor and student focus. It was found to be very important that the instructor is proficient with the technology and making sure that it is grade-appropriate (Wenglinsky, 1998). Also, the instructor's importance to the class is not less with the use of computers but is actually increased. Students viewed the instructor as the essential element in helping them to understand the content that they were learning (Schenone-Stevens, 1999). The perception of the students must also be considered. For instance, students tend to become easily lost/distracted by all the possibilities available when looking for information on the internet. Specific focus questions were necessary to give them guidance in their searches (Moss, 2000).

This research would seem to support my goal of using technology as a tool in improving my students' laboratory preparation as long as I take steps to address the concerns presented in the previous paragraph. One question that still remains is what instructional method would best suit this technology. Throughout much of the research there was one method that was consistently discussed more than others: self-paced, student-centered learning.

Student-Paced Learning

What advantages do students gain when learning individually? There are some key points about self-paced learning that are noteworthy:

> *"Learning in the Self-Study category is quite different. The student is in complete control of what is done next, mentally and physically. There is freedom to contemplate the relationship between two concepts, to explore a thought association, to work out something that was not being well understood" (Chang & Simpson, 1997)*

In the case of these pre-lab activities students need to move at whatever pace they need in order to take in the information. Rather than trying to "keep up" with the instructor (in lecture) or the rest of the class (in discussion) the student can put together their own way of organizing and understanding what they need to know. As indicated in the above quote, this will make the knowledge gained more personal and, it is expected, more easily recalled.

One aspect of the "self-study" description that varies widely at the high school level is the discipline. There is evidence both that more individual control increases students' learning and also that self-study can be less effective (Schackenberg, 1997). This is because a self-paced method requires discipline as well as focus; for those students who lack this rigor, this method can be an inefficient way of spending time and effort in learning (Chang & Simpson, 1997).

How effective, then, is this self-study method? Interestingly, the answer to this question seems very much linked to using technology. In fact, this instructional method is becoming more popular because of the growth in computer-assisted instruction (Schackenberg, 1997). One aspect of the argument for involving computers with various instructional methods is the level of comfort that many of today's teen-agers feel with technology (Kimble, 1999). In addition, technology is found everywhere in our modern life. This certainly warrants that even those students who are not as comfortable with technology should be prepared to participate in a technological world (Kimble, 1999).

Finally, the effectiveness of this self-paced approach, or any approach, depends on the attitudes that the students have. For the chemistry laboratory experience these attitudes depend on a number of factors including real-world connections, error-free procedures, and easily mastered manipulations (Howard & Boon, 1997). This indicates that whatever pre-lab instruction technique is to be used must carefully address all three of these factors in order to help the students be successful and interested in what they will be doing as they move along on an individual basis.

Linking Technology with Desired Goals

This research was very instrumental in guiding my ideas for how to approach my own research into combining technology with laboratory preparation. Two additional goals that I kept in mind were: 1) With the recent large investments in technology made by my school district I felt compelled to find worthy ways of putting it to use; and 2) I wanted to use this technology in practical and productive ways in my chemistry classes.

The area where I felt the greatest impact could be made was preparing our students for laboratory experiments; i.e. pre-lab preparation. Traditionally, students were prepared for lab by in-class lectures and brief demonstrations of the upcoming experiment the day before it was to be performed. Brief reminders regarding techniques and hazards were also given the day of the lab. Despite these efforts, I found that a noticeable number of students did not understand directions, did not realize the overall purpose of a particular lab, failed to read the lab ahead of time, or had simply not paid attention. Also, topics such as lab safety, equipment identification and use, and lab technique were usually given short shrift (due to time constraints) by this method of preparation.

What could be done to present a thorough covering of laboratory information in a way that keeps my students interested and helps them to better recall what they have learned? The proposed answer was to develop pre-lab activities involving multi-media technology for each laboratory experiment. Students would use PowerPoint presentations to proceed through the relevant information at their own pace. These activities should also help them to focus on the information that they will need to successfully complete a given lab. These presentations would involve pictures, video clips, audio clips, text, and internet links that show students the information needed for the specific lab. Also, I wanted to include links that connected ideas illustrated in the lab to other areas/applications. While this may not be the flashiest use of technology, I wanted to see how useful this approach would be before I expanded it beyond these relatively simple ideas.

Overall, then, the research and underlying goals support using technology in my proposed manner. As the class instructor, however, I must: 1) be up to date on the technology that we will be using; 2) present the pre-lab assignments with well-guided goals for the students so that they will focus on the necessary information for the lab and not get lost in the process of finding that information; 3) recognize that my role in this learning process will be altered to that of facilitator.

Curriculum: Midland Public Schools Chemistry Program

The pre-lab activities also needed to match the curriculum objectives of Midland Public Schools (MPS) and the state of Michigan goals and outcomes. Our accelerated chemistry program has a scope and sequence that is a step beyond the typical high school program. Students cover the same general content as would be expected in the typical high school chemistry program: quantitative measurement and analysis, behavior and structure of atoms, use of the periodic table and its atomic trends, chemical compound bonding and properties, chemical reactions and stoichiometry, properties of gases and their behavior, basic energy and thermodynamics, acid & base behavior, chemical equilibrium, reaction rates, and reduction-oxidation reactions. Each of these areas is covered with a greater depth , higher mathematical complexity, and faster pace than would be found in a typical high school program.

The MPS goals and objectives involve four main educational goals for the accelerated chemistry program (MPS, 1990):

To develop in the student an understanding of the fundamental principles and theories of chemistry.

To provide the student with opportunities to investigate and review application of these fundamental principles and theories.

To provide students with laboratory experiences that will aid in their inquiry approach to solving problems, attaining knowledge, and developing learning skills.

To prepare students for entrance into freshman college chemistry courses.

As part of the chemistry program I feel that the methods I propose to use in this study should fit very well. It is expected that the pre-lab activities will match each goal by:

1. *Providing additional background information regarding the principles behind each lab.*
2. *Applying the principles presented in the labs by exploring industries and businesses that use specific scientific principles in their daily work.*
3. *Enhancing the student's laboratory experience by increasing their knowledge of equipment usage, safety, and techniques.*

<u>Pre-lab Considerations, Design & Safety</u>

Before embarking on creating these technology-assisted pre-labs I found it useful to consider what other pre-lab techniques are commonly used or available for a typical chemistry program.

In looking over various texts and manuals it quickly becomes clear that the pre-lab activities developed for my research project appear to be unique. Beran's lab manual uses pre-laboratory assignments which ask primarily procedural questions that may be answered by skimming through the procedure (Beran, 2000). Another lab manual has no specific pre-lab tasks or procedures other than in the preface in which students are strongly urged to read the lab procedure before doing the lab (Holt: ChemFile, 2000). Older manuals provide pre-lab quizzes based on the procedure (Carmichael, 1990; Wilbraham, 1990;). Essentially these all boil down to "paper and pencil" tasks that do not provide the student with more than a superficial idea of what they will be doing or merely encourage students to "look" at the lab.

Another approach is found in the Holt chemistry lab manual (Jaeger & Weisker, 1996). In this manual nearly all labs are presented in a real-world context, such as placing the student in the position of a lab investigator trying to determine the best method for cleaning up a chemical spill. The pre-lab work in this book asks students to prepare a business report as well as materials lists and lab procedures that will be used to perform the lab. This method does a very good job of linking the classroom labs with real-world situations. However, the work does become quite involved and certainly would tax the abilities of many high school students to produce work of the level indicated in the manual.

Compared to these methods, the activities developed in this study seem to be unique. Students follow through the procedure and get a sense of what they must do, much like the Beran & Carmichael methods, and take pre-lab quizzes to further encourage doing the pre-lab tasks. The activities developed here go a step further and show the students what they will be doing in the laboratory. The links to related practical applications of the lab topic go well beyond anything presented in either of these manuals. Compared to the Jaeger & Weisker activities, those developed here are less tedious but still link classroom & lab ideas to the everyday world. Even better, many of the practical application links are to related industry and business web-sites. Thus, rather than having the students try to simulate a business in all of its complexity, the students can get right to the application of what they are studying. This certainly saves time and stress for the student while giving them a sense of how the topic that they are learning relates to the world around them.

Finally, safety is a very important issue in all pre-lab considerations. The most important aspect of lab safety happens before the lab is even begun: preparation. As Beran discusses in his preface to the 6th edition of his "Laboratory Manual for Principles of General Chemistry":

"Prepare for each experiment . . . advanced preparation will save you time, reduce the chances of personal injury and damage to equipment, and provide a more meaningful learning experience." (Beran, 2000)

Another important aspect of lab safety is the right of individuals to know the nature of the materials with which they are working. Students need to be aware that any chemical (even water) can be dangerous if used incorrectly (Jaeger & Weisker, 1996). This information is traditionally available in the form of the Material Safety Data Sheets (MSDS). However, students rarely, if ever, read this information. Using a self-paced, computer based tool in the pre-lab could be a means of providing the necessary information in a fashion that the students find more interesting. Information such as that presented in the MSDS can be put into context of a specific lab and thus make it more meaningful to the students.

Equipment identification is also an important part of laboratory safety. By incorporating pictures and video clips into the pre-lab activity the student can see how the equipment is used. This also leads into teaching students techniques in the lab by having them see how the instructor correctly uses the equipment in the video clips.

As discussed earlier, this computer-based method should allow for individual pacing in learning the information. Thus, if a student was distracted during one of the video clips he/she can simply replay it and see what was missed. It is much more difficult, if not impossible, to repeat these demos in a classroom. Those students who are quicker than others at picking up techniques can move along faster and not become frustrated by the slower pace of their peers. Additionally it has been shown that visual images, such as pictures or videos, can act as "conceptual pegs" that help students perform better laboratory procedures (Robinson, 1998). This suggests that students will have better ideas about exactly what they are supposed to use (what equipment to look for) and what they are supposed to do (what does it look like when they use it) when running the experiment after viewing the computer-based images.

All of the methods described above provide necessary safety data. The activities developed in this project certainly meet those presented in the lab manuals and also provide an additional benefit in that pictures can be included so that students actually see (and can recognize) the chemicals that they are using before they come in contact with them.

Pre-Lab Development & Preparation

Development Process

With all of this background knowledge in hand the next task was to develop the format for the pre-lab activities. I settled on the following plan: During the class period the day before the lab was to be performed students would go to our science computer lab and individually access a PowerPoint presentation specific to the lab. This presentation would present information regarding: 1) the overall purpose of the lab; 2) short background on principles and practical applications related to the lab; 3) safety information specific to the lab; 4) equipment identification and use ; 5) technique and procedural information. Students would then individually go through the pre-lab presentation and take notes on this information. When possible, still pictures or moving video images would be included as part of identifying equipment or explaining techniques. Internet links or scanned text would be used for practical application links. On the actual day of the lab students would first take a short pre-lab quiz (see Appendix B for quiz format) that checked for their understanding of the information presented in the pre-lab activity. Once the quiz was completed students would then go ahead and perform the lab.

During the summer prior to the 2001-02 school year I spent approximately four weeks developing the majority of PowerPoint presentations that I planned on using for this study. During the actual school year approximately one week (total) was spent in making adjustments to the presentations and finishing parts of the last few presentations.

As with any new idea much of time spent at the beginning of my work was to figure out how to use the technology. This included: 1) teaching myself how to use

PowerPoint; 2) learning how to use our school's digital video camera for both still and moving video & audio; 3) working with the iMovie program that translated the digital video camera images into usable videos on the computer; 4) learning how to most efficiently format video to fit on available storage media; 5) linking video, still pictures, scanned images, and internet links into PowerPoint. This took about a week and a half to reach the point of my being able to have it all function smoothly in preparing my presentations.

By the end of this first week and a half I had narrowed down the equipment needed in order to produce the presentations I had in mind to the following:

1. A facility with computers that are capable of handling the memory requirements of still pictures, moving video, audio, and having multiple applications of simultaneously. Fortunately we have such a facility, called the Exploratorium, in our building. This facility was built three years ago through private donations, grant monies, and industry support. All of the computers available to the students (MacIntosh G-3 models) in this lab are capable of supporting this kind of presentation and the teacher computers (MacIntosh G-4 and enhanced G-3 models) are capable of performing the necessary video editing.
2. Storage capacity large enough to handle the quantity of video and audio data that needed to be stored. The server that our building uses is not capable of running the multi-media technology very quickly when an entire class is accessing it at once. Because of this I employed the use of Zip disks in order to store the large video files that went with each PowerPoint presentation.

3. In order to include video a digital video camera was needed. Once the video was recorded the camera was then linked to the computer (via a USB port) and the video downloaded to the computer.
4. To edit and save the video in a less memory intensive format I used the Macintosh iMovie program. The video clips were edited with the iMovie program and then saved as Quicktime movies (saved as CD-ROM quality, medium sized videos). The iMovie program was also used to edit and save still pictures taken with the video camera.
5. A scanner was also very useful in preparing these presentations. Pictures and images from a variety of sources (such as magazine articles that have detailed color pictures) could be scanned and included in the PowerPoint presentations.
6. In terms of software requirements I ended up using PowerPoint 98 for Macintosh, Macintosh iMovie, and Quicktime 5.

After this first week and a half the rest of my time was spent in actually developing the presentations. I initially selected a dozen labs that I felt would benefit the most from this pre-lab activity format. They were selected based on a number of factors including procedural complexity, involvement of important lab techniques, historically challenging to students in terms of lab technique, variety of chemicals involved, ease of linking to everyday-world applications, and ease of translating into my proposed format. This list was ultimately narrowed down to nine labs (see appendix A-1 through A-9 for specific lab procedures): Lab #1: Measurement and Significant Figures, Lab #2: Graphical Analysis of Density, Lab #3: Analysis of Penny Composition, Lab #4: Compound Identification, Lab #5: Ionic Compound Formula Lab, Lab #6: Single

Replacement Reaction, Lab #7: Hydrated Salt Formula, Lab #8: Stoichiometry, Lab #9: Formula Mass of a Gas.

I went through each lab experiment and determined what procedural steps would be best demonstrated or explained using moving video. I then took the video camera to our regular chemistry lab and recorded the selected procedure steps as I performed them. Once recorded I went back to the computer lab and downloaded the video clips into the iMovie program for editing. I generally edited the videos down so that they each were under a minute in length. These finished clips were then saved as described in item #4 (above). Still images were also saved through the iMovie program as *.jpg images.

Once I had all the necessary video saved I began constructing the PowerPoint presentations. These generally followed the format of having a title page, a practical links/brief background page, equipment identification page, chemical hazards page, procedure and technique page, and a final reminders page. Video clips and still pictures were then pasted into the PowerPoint presentation so that they could be accessed by clicking on a button from the appropriate page. Internet links were established using tools already present in the PowerPoint program so that they too could be accessed by clicking on a button from the appropriate page in the presentation. Chemical hazards were obtained from Material Safety Data Sheets available both in the school as well as from on-line MSDS sources.

Sample Pre-Lab and Lab Format

At this point it is probably instructive to see how all of this came together for a given experiment. The following pages will show the finished example of pre-lab activity, pre-lab quiz, lab activity, and final write up employed in this study.

During the class period prior to the actual lab I took each of my chemistry classes to our computer lab. I planned on roughly thirty minutes as the maximum amount of time that students would be given to complete the pre-lab activity so this was done after we had accomplished other things in class (such as going over homework assignments, taking lecture notes, or other standard class activities). Students each picked up a Zip disk and went to their assigned computer to individually go through the PowerPoint presentation for the particular experiment. Students were instructed to take notes on any areas they felt were important. They were also reminded that they would have a quiz over this information the next day before they entered the lab. Figures 1 – 13 on the following pages present the screens and format for the pre-lab activity performed prior to the first lab (appendix A-1).

On the day of the lab, students came were given approximately five to ten minutes to take the pre-lab quiz before they entered the lab (see appendix B-1 for the pre-lab quiz that went with the "Compound Identification Lab"). Students then performed the lab. Once completed students then proceeded to answer the conclusion and analysis questions posed in the post-lab report (see appendix A-1 for the lab handout that went with lab #1 "Measurement & Significant Figures"). Students were generally given between two to four days outside of class, depending on the difficulty of the post-lab analysis, to submit their final report.

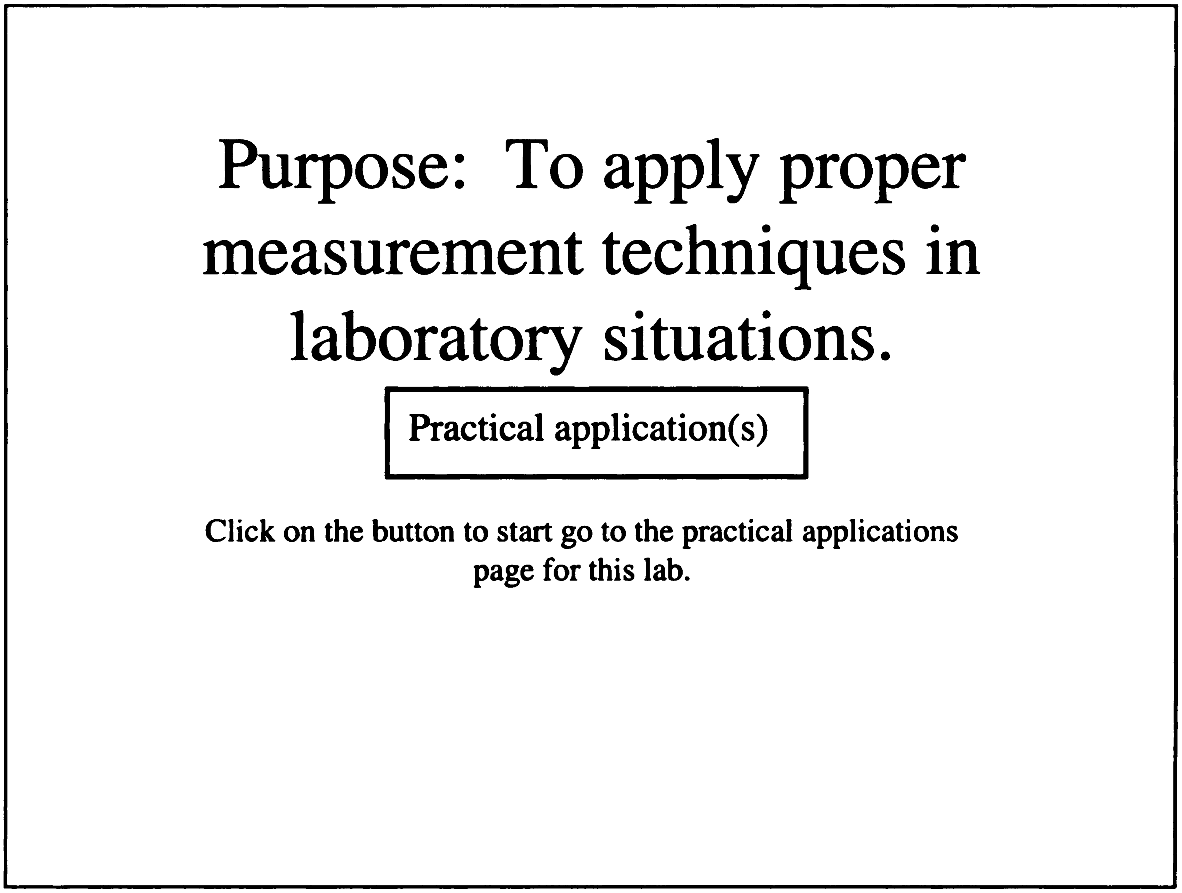
Figure 1

Scientific Measurement Lab

Units resemble sports officials: the only time you really pay attention to them is when something stupid happens.---
Steve Mirsky in *Scientific American*, August 2000, p. 96.

Introduction (title) page. Sometimes a humorous quote was included to help get the students thinking about the importance or relevance of the lab.

Figure 2



The lab purpose page. This clearly stated the purpose of the lab (i.e. the "why are we doing this?") and would send the students to the practical applications page where they could extend the lab concepts into the everyday world. Every pre-lab quiz had one question asking students to state the purpose of the lab.

Figure 3

Equipment List

- 3 metric rulers (meter sticks)
- Electronic balance
- Beaker
- Large graduated cylinder
- Thermometer probe
- pH probe

Click on the boxed-in equipment to see a picture or watch a video on how to properly use that equipment.

On this page students have the opportunity to see pictures of equipment with which they may not be familiar. Students can click on the buttons and go to pictures and/or video clips on how to properly use the indicated piece of equipment.

Figure 4

Hazards

There are no significant chemical hazards present in this lab exercise. However, proper care should be demonstrated in caring for equipment. The motto of "You break it, you bought it" will apply a majority of the time in cases of missing or broken equipment!

Some examples of equipment cost are listed below:

- 150 mL beaker: $2.60
- 400 mL beaker: $3.10
- 100 mL graduated cylinder: $5.90
- evaporating dish: $6.70
- crucible: $3.15
- 250 mL Erlenmeyer flask: $3.25
- 250 mL volumetric flask: $17.85
- electronic balance: $895.00
- analytical balance: $1,950.00
- computer probes: ~$50 each

The hazards page. Pertinent chemical and equipment hazards were listed here. All chemical hazards were summarized from Material Safety Data Sheets.

This particular lab did not involve any chemical hazards, but since it was the first lab of the year I felt that it was important for the students to realize the "cost factor" involved in the equipment that they were using. This helped to establish the importance of using all equipment carefully and properly.

Figure 5

Procedure

- Step #1
- Step #2
- Step #3
- Step #4
- Step #5
- Step #6
- Step #7
- Step #8
- Step #9
- Step #10
- Step #11
- Step #12
- Step #13
- Step #14
- Step #15
- Step #16
- Step #17
- Step #18
- Step #19
- Step #20

Read the steps in your procedure as you view this page. Click on the buttons to see video clips on how to perform the indicates steps.

Procedure page. Students would read through their procedure hand out (given in class prior to starting the pre-lab activity) while following this page. Those steps that were boxed in took students to another page on which technique video clips were shown.

Figure 6

Reminders

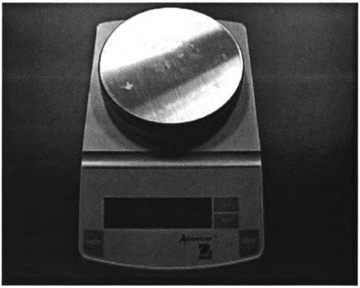
- Pre-lab quiz will be given on lab day.
- You will not be permitted into the lab if proper lab attire is not worn!
- Make sure that you clean up your station when the lab is complete.

Reminders page. This is the last main page of the presentation and offered some last reminders on lab expectations.

Figure 7

Electronic Balance

Step #6 of the procedure describes how to properly use the electronic balance.

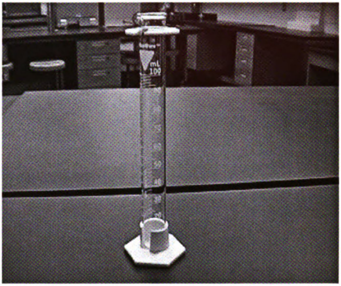


One of the equipment pictures that students accessed from the equipment page. Occasionally some notes were included with the picture in order to emphasize certain aspects of the use of the particular piece of equipment.

Figure 8

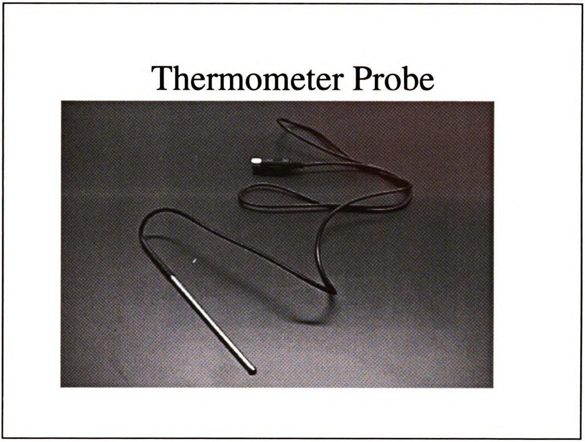
Large Graduated Cylinder

The plastic ring should be around the upper neck of the cylinder. That way if the cylinder tips over the ring will prevent it from breaking.



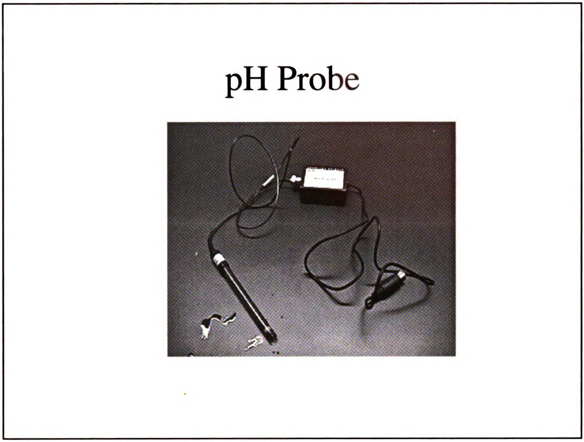
Another equipment picture that was reached by clicking on the buttons found on the equipment page.

Figure 9



Another equipment picture.

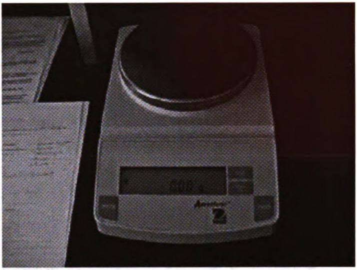
Figure 10



One more equipment picture. Later pre-labs had fewer equipment pictures since, by that point, students were familiar with equipment and did not need as many visual reminders.

Figure 11

Step #6: Using the electronic balance.



Click on the picture to start the video clip on how to perform this step.

Video clip page. Students reached this video by clicking on one of the boxed-in steps from the procedure page. Students were instructed to click on the video and watch (and listen!) to information regarding the use of this piece of equipment. Students were encouraged to take notes on equipment usage (there were regular pre-lab quiz questions regarding procedural steps and equipment usage).

Figure 12

Steps #8 & #9: Reading meniscus correctly (volume).

Click on the picture to start the video clip on how to perform this step.

Another video clip page. This one dealt with technique (rather than strict usage issues) as well as explaining the differences in the precision, accuracy, and sensitivity of two different measuring devices: a beaker vs. a graduated cylinder.

Figure 13

Practical application: What are some "unexpected" measurement units that you use daily?

There are a wide variety of units and measurements that we encounter daily. Those listed below represent just some of the more unusual units that you may have been affected by (either directly or indirectly). Click on any one of the links below for the practical application for this pre-lab.

- What does pencil hardness really mean?
- How heavy is a bushel?
- How much does a shovel hold?
- It's only a "gnat's eye" to the east!
- How big is a fist in astronomy?

Practical applications page. This page was reached from the purpose page (practical applications button). This featured links to internet sites that dealt with the concepts involved in the particular lab. This particular lab dealt with measurement and so students were sent to an on-line site dealing with all of the various measurement used in the world today as well as historically. Typically this practical applications page would present students with three different practical application options that they could investigate. Students were required to select at least one practical application and be able to describe its use and how it related to the concepts in the upcoming lab.

Laboratory Experiment Summary

The following laboratory experiments were used in conjunction with the pre-lab activities that are the focus of this research. Some of these experiments are "tried and true" labs that our chemistry program has used for years. Others are ones that I developed or acquired from various sources during my nine year teaching career. While none of these labs was entirely developed from a specific DSME class, the overall use of technology that I have incorporated in this research certainly finds its roots in the DSME classes as a whole. Additionally, the summary below does not represent all of the labs that my chemistry classes perform over the course of the year. There are others that I felt were not a good fit for my first try at using this computer-based pre-lab method.

Lab #1: Measurement & Significant Figures (appendix A-1)

This is the first lab that we perform in the school year and was based on my experience with using CBL technology in the DSME classes. Students used various probes, balances, rulers, and other measuring devices to see how precisely they can measure and then calculate various physical values for different objects.

Lab #2: Graphical Analysis of Density (appendix A-2)

In this "tried and true" lab, students used graduated cylinders and balances to determine the mass vs. volume for different metal pellets. The students then graphed the data and determined the slope of the in order to find the experimental density of each metal tested.

Lab #3: Composition (appendix A-3)

This is a lab that I learned about during an AP Chemistry conference during the summer of 2001. It involves students finding the percentages of copper and zinc present in a post 1982 penny. Students made notches in the edge of a penny and then placed the penny into hydrochloric acid in order to react away the zinc while leaving the copper behind. After drying, the remaining copper was massed and compared to the original penny mass.

Lab #4: Compound Identification Lab (appendix A-4)

This lab has been in place for many years. Students were to identify eleven unknown white substances based on their physical and chemical properties.

Lab #5: Ionic Compound Formula Lab (appendix A-5)

This is a brand new lab for our program that I picked up at an AP chemistry conference during the summer of 2001. Students reacted a strip of copper with a small amount of iodine in order to produce copper (II) iodide. They determine the masses of copper and the copper product (they do not know what the formula is ahead of time) and then use mole ratios to determine the correct product formula.

Lab #6: Single Replacement Reaction Lab (appendix A-6)

This is another long time lab in our chemistry program. This used the reaction between copper wire and silver nitrate solution to produce silver crystals. Students use the mass of the copper reacted and the silver produced in order to determine the mole ratio of the two metals and then write the correct single replacement reaction.

Lab #7: Hydrated Salt Formula Lab (appendix A-7)

Students heated samples of hydrated salts to determine the correct mass ratio, and then mole ratio, of water to salt and then correctly identify the salt.

Lab #8: Stoichiometry Lab (appendix A-8)

This lab is one that I have used for about four years. Students combined two aqueous salts and allow them to undergo a double replacement reaction that produced a precipitate. The students then filter the precipitate and compare the mass of what they obtained to the predicted mass using stoichiometry.

Lab #9: Formula Mass of a Gas (appendix A-9)

Students collected hydrogen gas in a eudiometer tube via the reaction of hydrochloric acid with a known mass of magnesium. They then calculated the mass of the gas using stoichiometry and the gas laws.

Assessment Tools

There were five tools used in analyzing the success of this technology based pre-lab approach. These tools are; (1) analysis of pre-lab (appendix B) scores; (2) comparisons of final lab grades to the 2000-01 school year; (3) comparisons of the actual time spent in the lab to the 2000-01 school year; (4) a student survey (appendix C) after completion of all of the pre-labs and labs; (5) anecdotal teacher observations.

The pre-lab quizzes (appendix B) were used to check the understanding of students in the class this year and see if the majority of them had a good understanding of what they were about to do and why they were about to do it. Overall lab scores were included to see if ultimately there was a difference in total lab work. While the pre-lab activities primarily stressed lab technique, safety, and lab purpose rather than post-lab analysis of data, I still hoped to see if a better understanding of the lab mechanics would translate into a better ability to perform post-lab analysis.

One tool used for analyzing the results of this study was a rough comparison of the time (plus or minus 5 minutes) taken on actual lab work this year compared to the previous year. Over the last couple of years I have been in the habit of noting how long it took for most (better than 3/4) of the lab groups to finish a particular lab. This is one, albeit a more anecdotal way, to see if there was any obvious difference between this format and that of the previous year. Finally, the student survey (appendix C) provided an opportunity to see if the students felt that they gained useable information from the pre-lab activities.

School Profile

In interpreting the validity of these measurement tools the demographics of the students in the classes are important. This study involves laboratory experiments performed in four sections of first-year accelerated chemistry classes at Midland High School in Midland, Michigan during the 2001-2002 school year. Midland High is one of two high schools within the Midland Public Schools system. Our school serves 1,550 students from Midland and a number of smaller, neighboring communities. The community of Midland is located in the Tri-Cities area of Michigan's Lower Peninsula (consisting of the cities of Bay City, Saginaw, Midland, and smaller communities).

Midland is most notable for being the world headquarters of Dow Chemical Company and Dow Corning Corporation. Midland is also home to Northwood University and Mid-Michigan Regional Medical Center. The nature of these industries and institutions leads to a very highly educated population within the community. This translates into high expectations from both parents and students for the level of education that they receive from our school.

The students enrolled in this accelerated chemistry program are typically sophomores with a handful of juniors and seniors included. This student population essentially represents the top 20% academically of the sophomore class. As would be expected these students are typically very academically motivated and tend to be more mature than their peers with regards to study habits and personal responsibility.

Analysis and Findings

The results for this investigation on using computer-based instruction for pre-laboratory work are presented in the following order:

(1) pre-lab (appendix B) scores

(2) final lab grade scores compared to the 2000-01 school year

(3) comparison of lab time spent compared to the 2000-01 school year

(4) student survey (appendix C) results

(5) instructor observations and general discussion

Pre-Lab Quiz Trends

An analysis of the trends in the pre-lab scores demonstrated some expected results as well as a couple of interesting observations. Figure 14 (following page) presents the average scores for the nine pre-lab quizzes that went with the nine labs for which the computer-based pre-labs were utilized.

Students generally did better on the pre-lab quizzes as the year progressed. Many students failed to use the first pre-lab activity seriously and were done very quickly. Not many took notes or thoroughly read/viewed all of the presentation and, on average, finished in well under fifteen minutes. Upon seeing the results of their pre-lab quiz (appendix B-1) they quickly realized that they were expected to remember details of the presentation such as specific hazard information as well as bigger ideas such as the overall purpose of the lab. Many students were unable to state the overall objective and could only vaguely remember equipment use information.

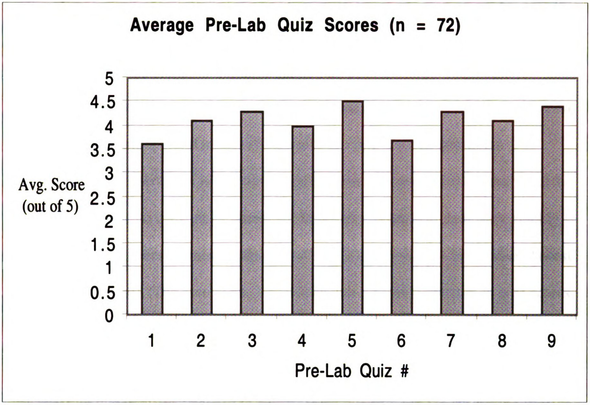


Figure 14

The students quickly learned the expectations regarding the knowledge that they should bring into the lab. I observed that they paid much more attention to the video clips in subsequent pre-labs and made sure that they took notes on such things as the overall purpose of the lab and important safety information. On the days in which a pre-lab quiz was to occur I observed that many students reviewed their notes prior to the quiz so that they could remember what they had seen and read the day before.

A couple of interesting observations came about as a result of comparing the pre-lab quiz scores over the entire study. The timing of the day that the pre-lab was performed compared to when the quiz and lab were done proved to be important. The pre-lab presentations for labs #4 and #6 were on Fridays followed by the quiz and lab on

Monday. These were also the lowest quiz scores after the very first. Students had taken notes with essentially the same detail as in other labs and performed quite well on the more note-friendly areas of recalling the overall purpose and the hazard information. They did worse, however, in the more video clip based technique questions, equipment identification questions, and internet-based practical applications questions.

Another observation is that the students became more efficient as they used the pre-lab activities. As previously stated, the first such activity was done very quickly (well under 15 minutes by most students) but also in a very superficial manner (lowest average quiz score). The second pre-lab activity saw a definite increase in quiz scores but also included most students taking 25 to 30 minutes to complete. By the time they completed the fifth pre-lab activity students were much better at narrowing down the information that they most needed to know. From this fifth pre-lab on, the majority of students were completed with the presentation within 20 minutes while still performing well on the pre-lab quizzes.

Post-Lab Report Trends

As can be seen from figure 15 (following page) there was essentially no measurable difference in final lab report scores compared to the 2000-2001 school year. This is the result of a number of factors. First, the pre-lab activities focussed primarily on the lab protocol and not on their analysis of the results, which is the basis of the post-lab grade. This indicates that the post-lab reports would not necessarily be a good measurement of the success of performing the pre-lab activities.

Secondly, students generally obtained clearer results in terms of their accuracy on labs compared to the previous year but did struggle more with extension and calculation questions involved in the post lab write-ups. The overall effect of this was to wind up with very similar final lab scores compared with previous years.

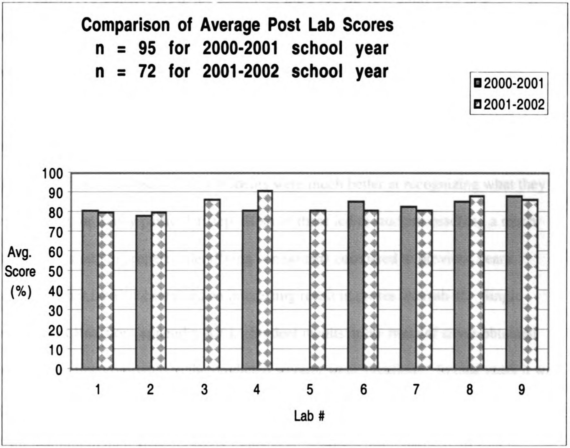


Figure 15

Another area that may have played a role in the outcome of the study was the students' perceptions on the purpose of the multi-media pre-labs. One study (Wilcox, 1997) suggested that students view the computer (or technology in general) as the overall point of a computer-related activity instead of viewing it as a tool to present information or learn. Some students may not realize that they should carry over information from the pre-lab beyond just the pre-lab quiz and apply it to the post-lab write-ups.

One notable exception to the trend of similar post-lab report scores was that of lab #4: Compound Identification (appendix A-4). This lab showed a noticeable improvement (10% increase) in lab scores for the 2001-02 year compared to 2000-01. This lab was particularly suited for using multi-media video clips because many of the steps rely on visual observations (such as subtle color changes and evidence of a small amount of precipitate) in order to correctly identify the various substances. I observed that students were much more confident about their observations when performing the various tests. Also, I observed that students were much better at recognizing what they were looking for in any particular step. Both of these led to students reaching a much better success rate in properly identifying compounds compared to previous years.

Another lab that contained an interesting result in scores was lab #6: Single Replacement Reaction (appendix A-6). Student results in the mass of silver obtained from this reaction compared to the predicted amount were excellent. In past years it was typical to have a large number of students with noticeable amounts of copper or copper salts remaining in their silver crystals. This year, however, only two groups (out of approximately 40) had any noticeable copper left behind with their silver. Part of this comes from the students' observing through the video clips presented in the pre-lab how many times and how careful they needed to be in order to completely rinse the copper ions from the silver. Although the overall scores on this lab were not significantly different from those of 2000-01, the results in this one particular area were much improved this year.

One last important note is that lab #3 (Penny Composition, see appendix A-3) and lab #5 (Ionic Compound Formula, see appendix A-5) were new labs this year. As such, no grade comparison could be made to the previous years. The final post-lab scores for these two labs are comparable to the scores of the other labs used in this study.

Trends of Time Spent in Lab

The area where the biggest change occurred was in the time spent in the laboratory. Figure 16 (following page) shows a definite decrease in the amount of time that students spent on lab work during this study as compared to the 2000-01 school year.

This overall decrease in time needed to complete labs is due to a number of factors that relate directly to the multi-media pre-labs used in this study. First, I observed that students were much better at recognizing the equipment that they needed in order to perform a given lab. Less time was spent searching for equipment or asking the instructor whether or not a particular piece of lab equipment was needed. There were also far fewer questions along the lines of "What is this?" posed at the start of labs.

Secondly, students were more familiar with the techniques needed to do particular steps. For instance, in lab #1 (Measurement and Significant Figures, see appendix A-1) students were much better about operating the electronic balances with care and also with keeping spills and other messes to a minimum. Students also referred to the information on the cost of equipment presented in the pre-lab activity as a reason for why they should operate it with the care described in the pre-lab video clips. In past years this lab typically took two full class periods for students to complete. It was not

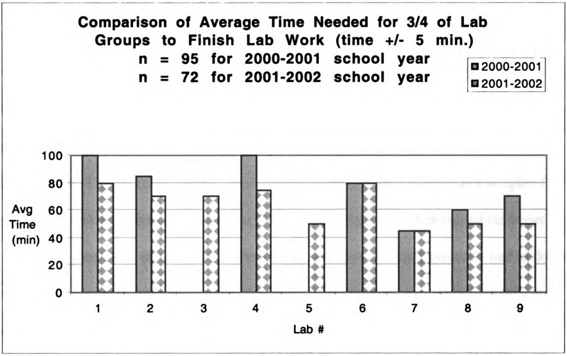


Figure 16

unusual to have some groups that still needed time outside of class to complete this lab activity. This year, however, students were able to complete the actual lab work in just over one class period and no groups needed additional time outside of class.

In lab #4 (Compound Identification, see appendix A-4) the pre-lab activity proved to be extremely valuable. Students could watch the video clips showing exactly how the tests should be performed and what changes, colors, reactions, etc. they should be looking for. This saved a lot of time in terms of students recognizing various "positive tests" and having to redo large parts of the lab because of incorrect observations. In past years students were constantly asking questions about their tests: "Is this what it should look like?" was a commonly heard refrain during the entire lab procedure. Since much less retesting of samples was needed the students were able to complete the lab in less time than needed by the past year.

Lab #9 (Formula Mass of a Gas, see appendix A-9) also showed an improvement in time needed for lab work. In the past this lab has often taken a period and a half for most groups to complete. This occurred because groups usually had to repeat the procedure at least once due to improper technique in collecting the hydrogen gas into the eudiometer. This year, however, nearly all lab groups were easily finished within one class period. This included the actual taking of the pre-lab quiz as well as a couple of groups that did have to repeat trials due to errors. Overall, this lab involved far fewer retrials and much less direct instruction on equipment set-up than I typically had to do in past years. Students were able to function more independently and efficiently this year while still obtaining good results.

Two labs, lab #6: Single Replacement Reaction (appendix A-6) and lab #7: Hydrated Salt Formula (appendix A-7), showed essentially identical time needed to complete lab work. These labs both involve fairly simple procedural steps that need to be done on consecutive days rather than during one continuous lab period. This meant that students had less control over how long particular steps or observations took than in the other labs used in this study.

Again it should be noted that lab #3 (Penny Composition, see appendix A-3) and lab #5 (Ionic Compound Formula, see appendix A-5) were new labs this year. As such, no time comparisons could be made to the previous years.

Student Survey Results

The survey (appendix C) provided some additional insight into the students' perception of the benefit of the pre-lab activities. This survey was given at the end of the year after students had completed a number of different lab preparation techniques in addition to the computer-based pre-labs. These techniques included: 1) reading the lab procedure on their own for homework, 2) developing a flow chart outlining the lab procedure, 3) developing a graphical-only flowchart outlining the lab procedure, 4) observing teacher demonstration of the upcoming lab procedure, 5) discussing as a class the lab procedure. When asked about how well prepared they were for the lab, their honest answers were revealing. Tables 1, 2, and 3 below present the student responses broken down by category. Questions #1 - #5 dealt with student perceptions regarding the multi-media pre-labs compared to other methods. Questions #6 - #10 dealt with student perceptions regarding their attitudes towards technology and their analysis of their own efforts on the pre-labs. Question #11 asked the students to recall information on the practical applications associated with the various pre-lab activities.

Table #1

Student Responses Presented as Percentages of Total Responses (n = 72)					
	1	2	3	4	5
Question #1	0	6.9	22.2	41.7	29.2
Question #2	0	0	29.2	33.3	37.5
Question #3	0	2.8	29.2	37.5	30.6
Question #4	0	2.8	11.1	22.2	63.8
Question #5	0	1.4	8.3	48.6	27.8

Table #2

Student Responses Presented as Percentages of Total Responses (n = 72)					
	1	2	3	4	5
Question #6	0	4.2	26.4	34.7	34.7
Question #7	0	1.4	11.1	37.5	50.0
Question #8	0	0	11.1	23.6	65.3
Question #9	0	15.3	31.9	30.6	22.2
Question #10	0	9.7	26.4	44.4	19.5

Table #3

Student Responses Presented as Percentages of Total Responses (Question #11 Only), (n = 72)			
0	1	2	3
13.9%	23.6%	37.5%	25.0%

In question #1, 71% of the students felt that the computer pre-labs prepared them at least a little better than other methods for the lab. I observed that this was reflected in the fewer questions asked by the students during the lab.

With regards to the issue of safety preparation (question #2), 71% of students felt that the computer pre-labs prepared them better than other methods. In fact 100% of the students felt that they were prepared at least as well as other methods. When asked about how well they felt that they remembered the safety information when performing the lab (question #10), 64% of students indicated that they almost always remembered the safety information given to them in the computer pre-labs. Another 32% indicated that they sometimes remembered the safety information. My own observations of student responses on the pre-lab quizzes as well as their behavior in lab indicated to me that the vast majority of them did remember the safety information and used it appropriately when performing lab experiments.

With regards to knowing the objective of each lab (question #3) 68% of students felt that the computer pre-labs prepared them better than other methods. My own anecdotal observations bore this out. Students had a much more "going through the motions" attitude in those labs in which computer pre-labs were not performed and tended to have more "why are we doing this?" kinds of questions. With regards to lab technique (question #4) 84% of students responded that they felt much better prepared, and more familiar with techniques, when using the computer pre-labs than with other methods (including when I demonstrated techniques for the class!). This linked quite well with students' responses to how well they remembered the techniques upon entering the lab (question #8). An impressive 89% indicated that the video clips that were a part of the pre-labs helped them to remember what they needed to do.

Discussion: Instructor Observations & Anecdotal Results

In addition to the measurements already presented there were a number of anecdotal results that are certainly worth mentioning.

The biggest change that resulted from using this technology-based pre-lab method was the time factor involved in all aspects of the lab. This can be directly attributed to the pre-lab activities that students engaged in prior to starting the labs. Students demonstrated much better recognition of how each procedure was supposed to work as well as the order in which individual steps needed to be performed. They also learned what particular steps of the lab protocol should look like, which led to less confusion regarding the procedure. I often overheard students making statements such as, "Oh yeah, this is supposed to look like . . .". Students also repeated trials or tests fewer times. I also observed that students also did a better job of recognizing lab equipment and what they were supposed to use for any particular lab. Their use of correct terminology and the fact that they spent less time trying to figure out what to use helped them to more quickly get equipment gathered and set up in order to begin the lab.

An area that I had not considered when I began this project also turned out to have a noticeable time savings. Lab make-ups for absent students became much easier once the technology-based pre-labs were used. In the past I would need to go through the make-up procedure and related information individually with every student who missed either the lab or the pre-lab information. With this technology-based approach I was able to simply give students the disk with the pre-lab activity and have them go through it before beginning the lab. This ended up saving me time because I did not need to continuously repeat information for multiple students; they could simply go through the information on their own prior to making up the lab. Once done with this make up they could then take the pre-lab quiz and begin the lab. Since the information was still very fresh in their minds they required less assistance from me when actually performing the lab. The students also would up getting done quicker with the make-up because they recognized much more quickly what they needed to do in regards to the procedure.

Safety was another area that I observed improvements due to the use of the pre-lab activities. I frequently heard students referring to pre-lab information when using chemicals in the labs. Instead of asking me "What will this stuff do if I . . ." students could tell me, for instance, that spilling the silver nitrate on their hands in the single replacement reaction lab (appendix B-6) would leave dark stains. By the end of the year students were familiar with the hazards of hydrochloric acid other than just vague ideas about it "being bad". The fact that nearly every solid used in any lab had an MSDS warning of "may cause respiratory irritation if inhaled" (a warning that came even with sodium chloride, a.k.a. table salt) was also not lost on the students; they quickly realized how much of a hazard this really was (i.e. very little for the amounts that we used) and were able to judge for themselves how truly hazardous something was. Because of the pre-lab activities students were much more familiar, and thus less paranoid, about the chemicals with which they were working. They recognized that they needed to work carefully and respect the chemicals with which they worked but did not need to become so nervous as to cause accidents.

Since there were fewer retests and retrials in the students' lab work a reduction in the amount of chemicals was also realized. Although no quantitative measurement of this was made a couple of examples show how much the pre-labs helped. In the ionic compound formula lab (appendix A-5) students had seen how much iodine was needed in the video clip that was a part of the pre-lab. Instead of deciding on their own how much "a few crystals of iodine" would be they had a visual cue to show how little was actually needed. Because of this barely half of a bottle of iodine crystals was consumed in order to get all four classes through the lab. I had originally estimated that three-fourths to one bottle would probably be necessary! In the compound identification lab (appendix B-4) only one of the sample containers had to be refilled over the course of the two days of labs. In the past at least half of the containers had to be refilled due to students needing to retest samples. Both of these examples demonstrate the savings in chemicals (and thus money!) that was realized from the use of the technology-based pre-lab activities.

Another conclusion that can be drawn involves the timing of the pre-lab work compared to the actual performance of the lab. Even with notes to study from beforehand, students did worse on pre-lab quizzes #4 and #6 (see figure 1) that were given after a weekend had passed between pre-lab and lab quiz. This seems to indicate that the students' ability to remember video information is very time dependent. If the lab is not performed within a day of the pre-lab then the students' memory of specific lab techniques shown in the videos really declines.

Another observation also plays a role in the results of the final lab scores (figure 2) and whether the pre-lab activities were effective in boosting post-lab report scores. Certainly every group of kids is different from year to year (even from hour to hour!) and the 2001-02 group was no exception. As a whole this group is less academically motivated than any previous accelerated chemistry classes I have taught. While they certainly did not present behavioral problems, this year's students consistently demonstrated a weaker work ethic than would normally be found in students taking this class. This was evidenced by their overall class average for the year (81% for 72 students completing the school year) compared to that of the 2000-01 group (86% for 95 students completing the school year). Because of this lower academic motivation I interpret the closeness of their post-lab scores compared to the previous year as a measure of success in using the technology-based pre-labs. This less motivated group managed to earn scores similar to a much more academically motivated group. I observed that the time factor played a role in this. Since this year's students were often done more quickly with labs than previous year's students they had more opportunities to ask questions of me in class regarding post-lab reports and calculations. This allowed them to get extra help that they otherwise might not have had in order to figure out how to analyze their results.

Conclusions: Does This Method Work?

What does this information tell us about the original question posed in this study: Does using multi-media technology in laboratory preparation improve student performance on laboratory exercises with regards to lab efficiency, technique, and understanding of underlying concepts? Let's look back at the three sub-questions of this overriding question.

(1) Do students better understand the essential information of a particular lab? Pre-lab scores (figure 1) indicate that students do understand the essential information better. Other than the first quiz, in which students were still getting used to expectations, and the sixth quiz, which took place after a weekend, students had high average scores on pre-lab quizzes that targeted these areas of essential information (including safety, lab objective, and procedural questions). The survey responses (tables 1 & 2) also indicate that students felt more fully prepared by this method and remembered it better than by other methods. My observations also indicate that students recognized equipment, performed techniques, and were better aware of hazards after having gone through the technology-based pre-labs.

(2) Do students perform better in the mechanics of the lab? This also appears to be an affirmative answer. The evidence for this was found in the shorter amounts of time needed (figure 3) to complete labs while still obtaining good laboratory results. This time savings mainly came about because there was less need to repeat trials due to errors, better student lab techniques, and better recognition of equipment. This improved mechanics was also demonstrated by a decrease in the consumption of chemicals. The majority of students also indicated (tables 1 & 2) that they felt the computer pre-labs

helped them in terms of recognizing what different tests or steps should look like. In terms of my own observations; I had far fewer questions from the students regarding "how do we" or "what is this" kinds of issues.

(3) Do students perform better on the post-lab report and related calculations? In this area the answer initially seems to be "no" (table 2). The averages on lab reports compared to previous years were very similar with no real differences observed. This may result from the fact that the pre-lab activities focused more on lab protocol and techniques rather than calculations and extensions that are needed for post-lab analysis. Thus, post-lab scores may not truly be an accurate measurement tool for the impact of the pre-lab activities on student lab performance. However, as indicated in the discussion, there is a measure of success in this area since this year's less academically motivated group was able to earn scores that were nearly identical, and in one case superior to (lab #4: Compound Identification, figure 2), their more academically motivated predecessors.

Perhaps the ultimate question is: Does the time gained in the performing of the lab justify the time necessary for students to do the pre-lab activities? I would respond with a resounding "absolutely"! Once the technique for making these pre-labs was worked out, the average one could be put together in around two hours depending on the amount of video footage that needed to be included. This time spent on developing the pre-labs paid off when students demonstrated improved efficiency in lab, better lab techniques, better recognition of lab purpose, improved equipment identification, and understanding of safety issues. They gained valuable information regarding safety and it reinforced lab techniques that are part of what students should be taking with them from a chemistry course. Also, many students demonstrated that they did remember the practical applications associated with the pre-labs (table 3) even though it had been at least three months between the survey and the last lab that they had performed. In fact, a handful of students even recalled the very first pre-lab practical application involving measurement, despite the fact that this lab was performed nearly nine months ago! These data indicate that students got more out of the lab activity by using the multi-media pre-lab activities than if they had not used them at all or gone through other methods of laboratory preparation.

Where to next?

The purpose of this research certainly is not to do a one-year change in the structure of the course and then let it drop. Based on the information gained from this study, there are a number of changes that I expect to make.

First, I plan on implementing multi-media pre-labs for each lab that is used in our chemistry program. The nine labs used in this study represent less than half of the total labs students do over the course of the year in this course. The time intensive nature of preparing these pre-labs will limit me to adding just a few each year, but over the next two years I will have all of the pre-labs developed. The most likely candidates for next year include an acid/base titration lab, a hydrogen peroxide decomposition rate lab, and a periodic table design lab. All three of these are good candidates because they each involve lab techniques and tests that depend on visual cues (making them very "video friendly") and/or are different from techniques already presented in other labs.

Secondly, the pre-lab information will be extended to include materials related to the post-lab analysis and write up. For instance, a sample calculation page can be included to give students a head start on recognizing how to go about performing more involved numerical analysis on some labs. I do want to avoid making the pre-labs too long; about twenty minutes to view/study seems to be a good length of time. Post lab reports will also include a question relating to the practical application link from the pre-lab to better reinforce the connection between the concepts behind a lab and practical uses of those concepts in the everyday world.

Finally, one area that I may develop, if class time permits, is to have students develop their own pre-lab activity in which they write their own lab protocol. I'll be interested to see if having students do this sort of pre-lab preparation gives them even better insight and understanding into the means by which chemistry and science in general need to be performed. This may also lend itself to being a "final lab exam" set up that can be included with the traditional written exam given at the end of the year.

Appendix A: Lab Procedure Hand-Outs

This appendix consists of the procedure hand-outs given to students for the various labs used as a part of this study.

Appendix A-1

Lab #1: Measurement and Significant Figures

Our first lab deals with proper measurement techniques and representation. In this lab you will be performing a series of measurements with different devices in order to practice using significant figures. All measurements must be in proper significant figures and all final calculations as well.

Two aspects of calculations are important when dealing with significant figures. The final number that is calculated can not have better precision than the numbers that went in to calculating it. In other words, the significant figures have to follow in order to correctly show how well the measurements were made. There are essentially two important rules:

1. For addition & subtraction: your final result can only go as far past the decimal as the fewest places past the decimal in the problem.

Ex. 4.213 cm + 5.2 cm = ______

The calculated answer is 9.413 cm, but since the 5.2 cm only went one place past the decimal the final answer can only be expressed as 9.4 cm (one place past the decimal)

2. For multiplication & division: your final result can only have as many total significant figures as the fewest present in your problem.

Ex. 5.6 cm × 2.716 cm = ______

The calculated answer is 15.2096 cm^2, but since the 5.6 cm only has 2 sig. figs. the final answer can only be expressed as 15 cm^2 (which shows only 2 sig. figs.).

You will need to keep these two rules in mind as you perform the calculations in this lab.

Procedure

1. Find measurement table #1 on your answer sheet. This table will be used for steps #2 through #4.
2. Use a ruler to measure the length and width of this sheet of paper. Record the measurements into the table. In the "total s.f." column indicate the total number of significant figures in each measurement. In the "decimal places" column indicate how far past the decimal your measurements went (i.e. to the tenths, hundredths, thousandths, etc. place).
3. Calculate the perimeter of the paper by adding the four sides. Make sure to express your final answer in the correct significant figures according to the rules given in the introduction.

4. Calculate the area of the paper in the usual manner. Again express your final answer in the correct significant figures according to the rules given in the introduction.
5. Find measurement table #2a on the answer sheet. This table, along with table #2b, will be used for steps #6 - #10.
6. Use the electronic balance at your station to obtain the mass of a stone. Record this as "balance #1" on your table.
7. Come to the front of the room and have the instructor obtain the mass of your object on a second balance. Record this as "balance #2" on your table.
8. Put some water into a beaker that has markings every 10 mL. Record the volume as "initial water volume". Drop your stone into the beaker and record the new volume as "final water volume". Calculate the volume of the stone and record this as "stone volume". Remember to record the volumes using correct measurement techniques and significant figures!
9. Repeat step #8 using a graduated cylinder.
10. Calculate the density of your stone using each of the four balance and volume combinations from the previous steps. Be sure to follow the rules for calculations with significant figures according to the introduction.
11. find measurement table #3. This table will be used for steps #12 - #15.
12. Fill your beaker about half full with water.
13. Use a thermometer and record the temperature of the water in "temp. #1".
14. Go to the front of the room and record the temperature using a temperature probe. Record this as "temp. #2".
15. While at the front of the room use the pH paper and record the pH of the water as "pH #1". Then use the pH probe and record the pH as "pH #2".
16. Find measurement table #4. This table will be used for steps #17 & #18.
17. Use your ruler to measure the length, width, and height of a box. Record these measurements into the appropriate spots on the table.
18. Using these measurement calculate the volume of the box. Remember to use proper significant figures in your results!

Conclusions & Analysis

1. Consider your temperature measurements from steps #13 & #14. Which device was more sensitive? How useful was this extra sensitivity to getting better measurements? Explain your answer. Do you know if one answer was more accurate than the other? Why or why not?
2. Consider the density calculations performed in step #10. Which combination(s) of measurements gave the answer with the most significant figures? The least?
3. Consider the pH measurements from step #15. Which device (paper or probe) was more sensitive? How useful was this extra sensitivity in getting better measurements? Explain your answer.
4. Compare your volume calculations in step #18 to at least two other people. How close are your results? Are they precise? Take the average of the three results (yours and the other two people) and use it as the true value to find the percent error of your volume. How good was your accuracy?

Table #1

	measurement	total s.f.	decimal places
length			
width			
perimeter			
area			

Table #2a

	balance #1	balance #2	initial volume	final volume	stone volume
beaker					
graduated cylinder					

Table #2b

Table #3

Temp. #1	Temp. #2	pH #1	pH #2

Table #4

length	width	height
volume calculation		

Scoring Summary

Organization calculations & written answers neatly presented **U / A**
data tables neatly completed w/ proper units _____ (3)

Precision & Accuracy

proper significant figures in all parts of lab _____ (6)
correct density and volume calculations _____ (3)

Conclusions & Analysis

sensitivity/precision analysis (question #1) _____ (4)
density calculation analysis (question #2) _____ (1)
sensitivity/precision analysis (question #3) _____ (4)
data comparisons (question #4) _____ (4)

note: U / A represents unacceptable and acceptable. Any labs given a "U" for unacceptable will be assessed a 10% grade reduction from the original score.

Appendix A-2

Lab #2: Graphical Analysis of Density

The study of chemistry involves both observing matter's properties as well as its changes. This nearly always involves a numerical measurement of the changes in those properties.

The purpose of this lab is to experimentally determine the densities of two different metals using graphical analysis. By now, the formula for calculating density should be quite familiar to you. In this lab, however, a graphical technique will be used rather than a single calculation. By plotting the metal mass versus the metal volume for various mass/volume combinations a line graph can be drawn. The slope of this line has units of grams per milliliter, a.k.a. density! This method is useful because it allows us to get an average of many different measurements without having to repeat each measurement multiple times.

Equipment

- electronic balance
- beaker
- scoop
- graduated cylinder

Procedure

1. Fill your graduated cylinder to about 20.0 mL with tap water. Record the exact volume of water. Then place the cylinder and water on the balance with a weighing boat underneath it. Once the mass becomes a steady value tare the balance to zero and leave the cylinder on the balance.

2. Use your beaker to obtain some of one of the provided metals from the front counter. Drop pieces of metal into the cylinder until the water level rises to the 25.0 mL mark. Record the exact volume then calculate the volume of metal that this represents.

3. Since your balance was already tared for the mass of the cylinder, water, and weighing boat the displayed mass should be the mass of just the metal. Record this mass.

4. Continue to add the same metal to the graduated cylinder until the water level reaches the 30.0 mL mark. Record the exact volume. Then calculate the volume of metal that this represents.

5. Once again, the displayed mass should be that of just the metal since the balance was tared. Record the mass.

6. Repeat steps #4 & #5 for the following volume marks: 35.0 mL and 40.0 mL.

7. Repeat steps #2 - #6 for the other two metals. Once done be sure to clean up your work area!

Conclusions & Analysis

1. Set up your graph showing metal mass (y-axis) versus metal volume (x-axis). For each volume/mass combination plot a point on the graph. Ultimately you should have enough points to draw a line (recall how to properly set up your graph as discussed in class!). The lines for all three metals can be placed on the same graph as long as a key is provided to identify which one is which.

2. Recall how to find the slope of the line. Since this graph has units of grams on the y-axis and mL on the x-axis, the slope will have units of g/mL (density!!). Calculate the slopes of each of your lines and report these as your experimental densities.

3. Compare your experimental densities to the accepted values given in class. Determine the percent errors. The allowable error on this lab is 5%. Based on this discuss whether your results were accurate. Also, discuss the precision of your data (on a graph precision is indicated by how closely your plotted points are to the best fit line). Do this for *each* metal!

4. Analyze the following errors and explain how they would affect the final densities (or if they would have no effect):
5. Air bubbles are trapped between the metal pieces when they are dropped into the graduated cylinder.
6. The graduated cylinder was not dried before the initial massing (excess water was present).

Scoring Summary

Organization	graph(s) properly set up (C & A #1)	____ (4)
	report & data neatly presented w/ cover page	U / A
	lab area sufficiently cleaned	U / A
Precision & Accuracy	final results within acceptable range	____ (3)
	correct significant figures	____ (2)
	precision & accuracy (C & A #3)	____ (6)
Conclusions & Analysis	slope calculations (C & A #2)	____ (6)
	error analysis (C & A #4)	____ (4)

Appendix A-3

Lab #3: Per Cent Composition of a Penny

One important use of chemistry is in determining the composition of matter. Whether analyzing a single chemical compound for purity or finding out the composition of a mixture of substances, chemistry is a very important means of examining matter.

In this lab we will be determining the composition of post 1982 pennies. Our overall goal in the lab is to determine the percentages of copper and zinc present in the pennies. This will be accomplished by using the fact that zinc is a more reactive metal than copper. Once the zinc is reacted away the remaining copper will be massed to find out the percent compositions of both elements.

Equipment

- 3 beakers or containers
- analytical balance
- metal file
- tweezers
- steel wool

Procedure

1. Obtain three beakers or other containers and label them #1, #2, and #3. In addition mark the beakers with your initials.

2. Obtain 3 pennies dated 1983 or later. Wash them with soap and water. Use a triangular meal file and make two "notches" on the edges of the penny (as shown in the pre-lab) in order to expose the zinc core. Clean the penny with steel wool until shiny. Dry them thoroughly and handle only with tweezers from this point on.

3. Place each penny on the analytical balance in order to obtain the mass. Record and then place them in their appropriate beakers. Make sure you know which penny is in which beaker (and the penny's mass)!

4. Add 20 mL of the 4 M hydrochloric acid (HCl) to each of the pennies. Place the beakers in the small fume hood at your lab station. Observe the reaction for a couple of minutes and record any observations. Leave the pennies to react overnight.

5. Carefully remove the pennies from their beakers and rinse with a stream of distilled water. Set the pennies aside on a paper towel. Empty the remaining solutions in the beakers down the sink with plenty of water. Rinse out the beakers several times and then fill them half full with distilled water.

6. Place the pennies into the distilled water and allow them to soak overnight.

7. Using tweezers, remove the copper "skins" and immerse them in an acetone solution for about a minute. Remove them and allow to air dry for about 5 minutes.

8. Record the final mass of the copper "skins".

Conclusions & Analysis

1. Calculate the mass of zinc that must have reacted. Then, based on your previous data and your zinc calculation, determine the percents of both copper and zinc present in the original penny.

2. Compare your three trials to each other. How was the precision of these trials? You will be given the actual percentages in class. Determine the percent errors for your trials and discuss your accuracy (the acceptable error for this experiment is 5%).

3. Analyze the following errors and explain how they would affect the final percentages (or if they would have no effect):
   a) A penny is not thoroughly cleaned leaving dirt on the penny that does not react with the acid.
   b) A more concentrated solution of hydrochloric acid is accidentally used which causes some of the copper to react as well as the zinc.
   c) Not all of the water is removed from the penny at the end of the experiment.

Scoring Summary

Organization	data tables set up w/ proper units	____ (2)
	report and data neatly presented w/ cover page	**U / A**
	lab area sufficiently cleaned	**U / A**
Precision & Accuracy	final results within acceptable range	____ (4)
	correct significant figures	____ (2)
	precision & accuracy (C & A #2)	____ (3)
Conclusions & Analysis	composition calculations (C & A #1)	____ (3)
	error analysis (C & A #3)	____ (6)

Appendix A-4

Lab #4: Using Physical & Chemical Properties: Qualitative Analysis

.3 Chemistry

Qualitative analysis is a laboratory technique used in identifying chemicals by their physical and chemical properties. By following a "flow chart" type of lab procedure chemicals that share similar properties can be separated and identified in a series of physical and chemical tests. In this lab, you will be asked to correctly identify eleven similar household compounds (all of which are white substances & most of which are powders). It will be very important that you follow each step carefully and use good techniques in order to correctly identify the various compounds.

The compounds involved are: table salt (sodium chloride), baking soda (sodium bicarbonate), washing soda (sodium carbonate), drain cleaner (sodium hydroxide), boric acid, plaster of Paris (calcium sulfate), calcium supplement tablets (calcium carbonate), cornstarch, fruit sugar (fructose), table sugar (sucrose), and Epsom salts (magnesium sulfate).

Procedure

1. Note the provided data table. Once you identify the substances listed you should write down the ID number alongside the compound's name.

2. Obtain eleven small test tubes. Number these from one to eleven to correspond to the compound numbers.

3. Test each solid for water solubility by taking a *pea-sized* piece and placing it in a test tube with 10 mL of water. All of the compounds are water soluble *except* the cornstarch, plaster of Paris, and the calcium supplement. Do not discard the solutions!

4. To the three test tubes containing the insoluble (did not dissolve) samples add 2 drops of iodine solution. The iodine will turn a deep blue color when it forms a complex (simple chemical reaction) with cornstarch. Note which sample number corresponds to this color change and record that number as being the cornstarch on your table.

5. Obtain *new* pea-sized samples of two other insoluble samples left over from step #4. Place each sample in a clean test tube and add 10 mL of vinegar to each test tube. Vinegar will react with the calcium supplement to produce bubbles of carbon dioxide gas. By process of elimination the other sample must be the plaster of Paris. Record the numbers of these samples next to the appropriate compound in your table.

6. *You should now have 8 unidentified compounds remaining that all dissolved in water.* To these 8 test tubes (from step #3) add 2 drops of phenolphthalein. This organic substance will turn a "hot pink" color for the washing soda and the drain cleaner. All of the other solutions will remain clear or very faint pink. *Do not discard the solutions that are clear or faint pink.*

7. *Obtain new pea-sized samples of the samples that you have identified to be the washing soda or drain cleaner.* Put these in clean test tubes and add 5 mL of vinegar to each one. The washing soda will react with the vinegar to produce bubbles of carbon dioxide gas. By process of elimination the other sample must be the drain cleaner. Record the numbers of these samples next to the appropriate compound in your table.

8. *You should now have 6 unidentified compounds remaining (from step #6).* To each of these remaining solutions add 5 mL of sodium hydroxide solution. A white solid (this may actually look "cloudy"), called a precipitate, will form in the Epsom salts *(note: due to the previously added phenolphthalein this solid may appear pink instead of white).* Record the number of the solution forming the precipitate as being the Epsom salts in your table.

9. *To the remaining 5 solutions (from step #8)* add 5 mL of fructose test solution. Then add 5 mL of copper (II) sulfate solution. A green-brown-orange (very funky looking!!) solid will form in about 5 minutes. The other solutions should all be various shades of blue. The sample forming the multiple colors is the fructose. Record the number of the solution forming this precipitate as being the fructose in your table.

10. *Obtain a fresh pea-sized sample of each of the four remaining compounds* and place them in clean test tubes. Add 5 mL of vinegar to each one. The vinegar will react only with the sodium bicarbonate to produce bubbles of carbon dioxide gas. Identify the sodium bicarbonate in the table.

11. *Obtain a fresh pea-sized sample of each of the three remaining compounds and place them in clean test tubes.* Add 10 mL of rubbing alcohol (isopropyl alcohol) to each test tube. Only the boric acid will dissolve very well in the alcohol. Identify this boric acid in the table.

12. Put about a spoonful of the remaining two compounds (fresh samples of each again!) into separate larger test tubes. Add 15 mL of water to each one. Gently heat each test tube over a Bunsen burner. The sucrose is more water soluble and will form a relatively clear solution. The table salt may not all dissolve and will probably form a slightly white-appearing solution. Identify these last two compounds in your table.

Conclusions & Analysis

1. You should have your data table filled in with numbers of samples corresponding to the various substances. Double-check to make sure that you haven't used any number more than once or missed a number!

Data Table

compound	number
table salt	
baking soda	
washing soda	
drain cleaner	
calcium tablet	
plaster of Paris	
cornstarch	
fructose	
sucrose	
Epsom salts	
boric acid	

Scoring Sheet

Organization	- flowchart & table neatly presented	**U / A**
Precision & Accuracy	- compounds correctly identified	____ (11)
	- logical & appropriately detailed flowchart	____ (9)

Appendix A-5
Ionic Compound Formula Lab
.3 Chemistry

Ionic compounds are found nearly everywhere in our daily lives. From salt on French fries to photography to gems and minerals these types of compounds are very useful. Our purpose in this lab is to determine the formula for an ionic compound made of copper and iodine. The calculations involved are very similar to those that we have already performed in class.

Equipment	- tongs	- analytical balance
	- tweezers	- Bunsen burner & striker

Procedure

1. Clean and dry a small beaker. This will be used to hold the copper strip throughout the lab. All massings will be done in this beaker, but you will not need to obtain the mass of it in order to do the rest of the calculations.

2. Clean the surface of your copper strip with steel wool. Place the cleaned strip into the beaker and determine the mass. After the strip has been massed do not touch the surface with your fingers. If necessary, hold it by the sides like you would for a photograph.

3. Bend the strip to a concave shape and place a few crystals of iodine onto the strip.

4. Under a fume hood, use tons to hold the copper strip and gently heat the strip to allow the iodine and copper to react.

5. Continue to heat gently until no more purple vapors are released. A white/yellow solid should be left on the surface of the copper strip. Be careful not to overheat as this will damage the product or cause it to flake off of the strip.

6. Carefully place the strip into the beaker and obtain the mass of the copper/iodine product. With this mass the mass of iodine atoms that reacted can now be determine by subtracting the original, pure copper mass from the mass of the product.

7. Remove the strip from the beaker and remove the product by gently scraping it off of the strip using a scoop. Rinse with distilled water and hold the strip over a flame to dry it. Place the strip into the beaker and obtain the mass of the remaining copper. Subtracting this from the original copper mass will give the mass of copper reacted.

8. If time permits, repeat this procedure at least one more time. Otherwise, obtain data from two other groups so that precision and accuracy can be determined.

Conclusions & Analysis

1. Set up a data table that will record three trials of the data: mass of beaker w/ Cu, mass of beaker w/ product, mass of I used, mass of beaker w/ remaining Cu, mass of Cu used.

2. Calculate the mols of both copper and iodine used. Then determine the formula for this compound of copper and iodine. Also give the name for this compound.

3. Explain how the following errors would have ultimately affected the final calculated ratio of Cu to I:
   a) Some or the product was lost before the final mss was taken.
   b) The strip was not dried before the final mass was obtained.

4. Describe how the electrons must have moved between the original atoms in order to make this compound. Give a dot diagram to illustrate this movement.

5. Based on the results from your group and the other two groups how precise are the final results? How confident are you that the answers are correct? Explain your reasoning.

6. Antimony forms two different compounds with chlorine. These two compounds have vastly different properties from each other. Determine what these two formulas are if one antimony/chlorine compound contains 46.8% chlorine while the other compound contains 59.3% chlorine.

Scoring Summary

Organization	lab write up neatly presented w/ cover page	**U / A**
	data table neatly presented w/ proper units	**U / A**
Precision & Accuracy	correct final formula	_____ (5)
	error analysis (#3)	_____ (4)
	precision discussion (#5)	_____ (3)
Conclusions & Analysis	correct calculations & neatly organized (#2)	_____ (5)
	bonding discussion (#4)	_____ (4)
	extension question (#6)	_____ (4)

Appendix A-6
Reaction of Copper & Silver
(Single Replacement Reaction)

One important use for chemical equations is to be able to find relationships between the elements (or compounds) involved. In this experiment we will use the relationship between copper and silver in a type of reaction called a single replacement reaction. From this we can determine the charge that the copper takes during the reaction.

Equipment

- 150 mL beaker
- balance
- copper wire

Procedure

1. Obtain one of the pieces of copper wire. Clean it with steel wool. Obtain the mass of the wire and record it into the table.

2. Get the mass of a clean 150 mL beaker and record.

3. Fill the beaker about 1/2 to 3/4 full with silver nitrate solution. Coil the copper wire and hook it over the edge of the beaker so that a good portion of the wire is in the silver nitrate solution.

4. Cover the beaker with a watch glass. Observe for a few minutes and record what you see. Place the beaker in your drawer overnight.

5. Carefully remove the copper wire from the beaker. Rinse off the wire with distilled water in order to remove the silver crystals collect the crystals in the beaker). Set the wire aside to dry.

6. Carefully decant the solution into a second beaker leaving the silver crystals behind in the original beaker. Rinse the silver crystals 3 times with 10 mL of distilled water each time. Look to see if any pieces of copper remain mixed in with the crystals. If any copper remains you will need to add some more silver nitrate solution to react with the copper and then repeat the washings described in this step.

7. Set the silver crystals aside to dry overnight. get the mass of your dry copper wire and record this in the table.

8. When the silver crystals are dry get their mass and record.

9. Calculate the mass of copper reacted. Convert the masses of the elements into mols.

Conclusions & Analysis

1. Set up a neat, organized data table to record the necessary information from the lab: mass of beaker, initial mass of Cu, final mass of Cu, mass of reacted Cu, mass of beaker and Ag, mass of Ag produced, mols of Cu reacted, and mols of Ag produced.

3. Compare the mols of Cu to the mols of Ag. Determine the simplest whole number ratio between them.

4. The ratio that was found in #1 tells you the coefficients for the balanced equation between the copper and silver. Using this information, fill in the missing values in the reaction below and then balance it.

$$\underline{\ ?\ }\ Cu\ (s) + \underline{\ ?\ }\ AgNO_3\ (aq) \rightarrow \underline{\ ?\ }\ Ag\ (s) + \underline{\ ?\ }\ Cu_{??}(NO_3)_{??}$$

5. What charge must the copper have taken when it underwent the reaction? Explain how you can tell.

6. Based on your observations of the reaction how could you tell that a rection was occurring? Give at least two observations.

7. Describe how the following errors would have affected the final ratio of copper to silver in this reaction:
   a) Some silver crystals were accidentally poured out when the solution was decanted.
   b) Some copper crystals remained in with the silver crystals after the washings were complete.

Scoring Summary

Organization	lab report neatly presented w/ cover page	**U / A**
	data table neatly presented w/ units	**U / A**
Precision & Accuracy	correct ratio of Cu to Ag	_____ (4)
	correct balanced equation (#3)	_____ (4)
Conclusions & Analysis	correct mol & ratio calculations (#2)	_____ (4)
	copper charge analysis (#4)	_____ (2)
	reaction observations (#5)	_____ (2)
	error analysis (#6)	_____ (4)

Appendix A-7
Hydrated Compound Decomposition
.3 Chemistry

Hydrated salts are a special class of salts that have water as a part of the formula. These water molecules are basically "trapped" inside of the ionic compound crystal structure and are thus included as part of the formula. Although they often do not look "wet", they may still contain significant amounts of water within them. The purpose of this lab is to use a decomposition reaction to determine the formula of an unknown hydrated salt.

Equipment

- Bunsen burner
- crucible & cover
- scoop
- ring stand & ring
- clay triangle
- balance

Procedure

1. Set up a neat, organized data table to record the following information: mass of crucible & cover, mass of crucible & cover w/ salt, mass of salt, mass of crucible & cover w/ dehydrated salt, mass after reheating, mass of dehydrated salt, and mass of water. Set this table up to allow for up to three trials plus a column for averages.

2. Light the bunsen burner and place your cleaned crucible w/ cover into the clay triangle. Allow it to heat for a couple minutes so as to remove any water. From this point on you should only handle the crucible with tongs, not with your hands.

3. Let the dish cool and then determine the mass of the crucible w/ cover.

4. Place some of your hydrated salt into the crucible and obtain the mass. Calculate the mass of the salt.

5. Place the crucible into the clay triangle and begin heating. Heat gently at first, then increase the flame to heat more strongly after a couple minutes. You should heat for at least 10 minutes.

6. Remove the dish from the bunsen burner and let it cool for at least 5 minutes before obtaining the mass.

7. Place the crucible back over the flame and heat for about 3 – 4 more minutes. Remove from the flame and let it cool before getting its mass.

8. If the mass from step #7 is the same as step #6 then proceed to step #9. If the masses differ by more than 0.1 g then repeat step #7 until the masses agree within this range.

9. This last recorded mass should be labeled as the final mass. Dispose of the dehydrated salt in the waste container on the front counter.

10. From the final mass calculate the mass of dehydrated salt. Also calculate the mass of water that must have been present.

11. If time permits, repeat the process for another trial.

Conclusions & Analysis

1. From your experimental data, determine the percent of salt and the percent of water that must have originally been in the hydrated salt. Compare this to the possibilities given in class and identify which salt you had.
2. Write out the balanced decomposition reaction for dehydrating your salt. Include physical states.
3. Explain how the following errors would have altered your final percentages of salt and water:
    a) The salt was not heated until its mass was constant.
    b) The balance was improperly calibrated and always read .50 g too high.

4. Naming of these types of salts is rather simple. The salt formula is named according to the standard naming system that we have already been learning. The presence of water is indicated by the word "hydrate" being added to the name. Finally, the number of water molecules per each salt unit is indicated with a Latin prefix (such as mono (one), di (two), tri (three), and so on). Using this naming system, write the formula or name for each of the following salts:

a) copper (II) sulfate pentahydrate	e) $BaC_2O_4 \bullet 2\ H_2O$
b) cobalt (II) phosphate octahydrate	f) $Ba(OH)_2 \bullet 8\ H_2O$
c) calcium chloride hexahydrate	g) $MgCO_3 \bullet 3\ H_2O$
d) calcium sulfate dihydrate	h) $Hg_2O \bullet H_2O$

Scoring Summary

Organization	report neatly presented w/ cover page	U / A
	data table neatly presented w/ units	U / A
Precision & Accuracy	correct identification of salt	_____ (5)
	proper sig. figs.	_____ (1)
Conclusions & Analysis	correct & neat calculations (#1)	_____ (5)
	balanced decomposition rxn. (#2)	_____ (2)
	error analysis (#3)	_____ (3)
	hydrated naming (#4)	_____ (4)

Appendix A-8
Reaction Stoichiometry Lab
.3 Chemistry

As seen from the practical applications of stoichiometry in the chapter, there are many applications for this technique in chemistry. One use of this in the real world stoichiometry can be used to find the amount of dissolved substances in hard water. Hard water often consists of calcium and magnesium ions. When these come in contact with certain ions in tap water they will form a precipitate (solid) which is often found as the "scale" that forms on pipes and inside hot water heaters. In this lab we will use a similar reaction to find the concentration of strontium nitrate present in water.

Equipment	- graduated cylinder	- 2 beakers	- balance
	- filter paper	- funnel	- scoop
	- distilled water	- ring stand & ring	

Procedure

1. Set up a data table to record the indicated information in the lab.

2. Measure about 10 – 15 mL of strontium nitrate solution and put it in one of your beakers. Be sure to record exactly how much strontium nitrate solution you're using.

3. Pour a little over twice as much sodium phosphate solution into your beaker as what you poured in for strontium nitrate (i.e. if you used 13.0 mL of strontium nitrate solution then pour in a little over 26.0 mL of sodium phosphate solution).

4. You should now have a cloudy, white precipitate that formed in the beaker. Let this settle for a couple minutes while you do the next step.

5. Obtain a piece of filter paper and get its mass. Record this mass. Fold the filter paper for use in a funnel and set this on your second beaker.

6. Carefully pour the contents of the first beaker through the filter paper. The precipitate should remain in the filter paper and a clear solution should come through the filter paper. Be patient

7. Rinse out you first beaker with distilled water until all of the precipitate is in the filter paper.

8. After all of the precipitate is on the filter paper gently rinse the paper with some distilled water to make sure and get rid of any impurities.

9. Allow the filter paper to dry. Once dry, obtain the mass of the paper & precipitate. Then calculate the mass of just the precipitate. Record both of these values.

Conclusions & Analysis

1. Write out the reaction between the strontium nitrate and the sodium phosphate. What type of reaction is this? Give the ionic and net ionic equations for this reaction.

2. Using the mass of the strontium phosphate product (the precipitate) as your starting point, calculate the grams of strontium nitrate that must have originally been present.

3. Use the mass that you found in question #2 and the volume of strontium nitrate solution to calculate the concentration (in grams per milliliter) of the solution.

4. Compare your results from question #3 with at least two other groups. What can be said about the accuracy and precision of the final results?

5. Sodium carbonate can be used to make a pretty good water softening agent. Explain why sodium carbonate would work for removing calcium, strontium, and most other ions from water.

6. Explain how the following errors would affect the final results:
1. The mass of strontium phosphate was 1.18 g but was recorded as being 1.81 g.
2. Not all of the precipitate was washed onto the filter paper from the beaker.
3. The filter paper & precipitate were not dry when the final mass was taken.

Scoring Summary

Organization

	U / A
- lab neatly typed w/ appropriate cover page	
- data table neatly presented w/ proper units	_____ (2)

Precision & Accuracy

- correct significant figures	_____ (1)
- final answer within acceptable error	_____ (5)

Conclusions & Analysis

- correct reaction (#1)	_____ (4)
- correct stoichiometry calculation (#2)	_____ (4)
- solution concentration (#3)	_____ (2)
- results comparison (#4)	_____ (2)
- carbonate application (#5)	_____ (2)
- error analysis (#6)	_____ (3)

Appendix A-9

Formula Mass of a Gas

.3 Chemistry

As we have already seen, it is possible to do stoichiometry for gases by combining the calculations for the reaction with the ideal gas law. One we know the volume, temperature, and pressure finding the mols of the gas is easily calculated. This value can then be used for stoichiometry.

In this lab, our goal is to calculate the mass of a piece of magnesium by using the volume of hydrogen gas as our starting point.

Equipment	eudiometer tube	1 holed stopper
	thermometer	large bucket or beaker
	string	

Procedure

1. Fill your bucket with water from the room temperature jug at the front of the lab. Use a thermometer to record the temperature of the water. Record this in your data table. Also obtain the day's atmospheric pressure from your instructor. Record this as well.

2. Obtain a strip of magnesium from your instructor. Use the electronic balance to obtain the mass of the magnesium.

3. Roll the magnesium into a small coil and tie it will a piece of string (about 20 cm long).

4. Obtain 10 mL of hydrochloric acid and put this into the bottom of your eudiometer.

5. Fill the eudiometer the rest of the way (completely full) with distilled water. Fill the eudiometer slowly so as to prevent the acid from mixing very much with the water.

6. Put the magnesium strip into the eudiometer so that it hangs about 5 cm down into the tube. Place the stopper into the end of the tube so that the stopper holds the string (which will help keep the magnesium in place). Some water will be displace from the tube when you do this. Make sure that no air gets in as you do this step!

7. Flip the eudiometer over and place it into your bucket. Clamp it in place with the ringstand & clamp. Observe how the acid slowly mixes and makes its way to the magnesium. You should see bubbles forming on the magnesium as the acid reaches it and begins reacting.

8. Once the reaction has stopped (no more bubbles appear), record the volume of gas that you've collected by reading the volume from the eudiometer. If your eudiometer water level is higher than the level in your bucket then get a ruler and measure the height of the water column. Record this height.

9. Repeat steps 2 - 8 at least one more time so as to get an average. If time permits you may be able to get three trials in. Be sure to clean up your area once you are done!

Conclusions & Analysis

1. Write out the balanced equation between the magnesium and the hydrochloric acid (including physical states).

2. Use the magnesium mass to do the stoichiometry and calculate the mass of hydrogen gas produced.

3. Calculate the pressure of the dry hydrogen gas by accounting for the water vapor present in the eudiometer.

4. Use the mass, volume, pressure, and temperature of the collected hydrogen gas to calculate the experimental formula mass of hydrogen gas.

5. Of course you know what hydrogen's formula mass really is. Compare your result from #4 with hydrogen's actual formula mass. Determine your percent error. Suggest at least two possible error sources (other than "human error" or other lame excuses) for any percent error that you found. You should also explain *how* those errors would affect your final results. ***Strong suggestion: the larger your error, the better your explanation had better be!***

Scoring Summary

Organization		
	lab report neatly presented w/ cover page	<u>U / A</u>
	data table neatly presented w/ proper units	<u>U / A</u>
Precision & Accuracy		
	final answer within allowable error & error analysis (#5)	____ (8)
	correct significant figures	____ (2)
Conclusions & Analysis		
	balanced chemical equation (#1)	____ (2)
	stoichiometry calculations(#2)	____ (3)
	gas calculations (#3 & #4)	____ (10)

Appendix B: Pre-Lab Quizes

This appendix consists of copies of the pre-lab quizzes given to students the day that they began each lab.

Appendix B-1

Pre-Lab Quiz #1

Answer the following questions regarding the lab you are about to perform.

1. What is the overall purpose of this lab?

2. Describe how to properly measure volume using a graduated cylinder.

3. While there are no chemical hazards in this lab there are still other things to be concerned about. Describe one of these concerns and provide an example that demonstrates it.

4. Other than the graduated cylinder, what are three other pieces of equipment that you will need for this lab?

5. Describe, with sufficient detail, one of the practical applications related to measurement discussed in the pre-lab.

Appendix B-2
Pre-Lab Quiz #2

Answer the following questions regarding the lab you are about to perform.

1. What is the overall purpose of this lab?

2. Which of the three elements used in this lab is potentially the most hazardous with regards to long-term exposure? How significant is this hazard in this particular lab?

3. Describe the process by which you will determine the volume of the metal in the graduated cylinder.

4. Describe the type of graph that you looked up in the practical applications section. What are some potential disadvantages/problems with this type of graph?

5. Describe the process by which you will determine the mass of the metal in the graduated cylinder.

Appendix B-3

Pre-Lab Quiz #3

Answer the following questions regarding the lab you are about to perform.

1. What is the overall purpose of this lab?

2. Describe the precautions you must take when working with the analytical balance.

3. Describe what you must do in order to properly expose the zinc core of the penny.

4. List (briefly describe) the hazards associated with the substances in this lab. Which of these hazards is of greatest concern?

5. Describe your practical application for this lab.

Appendix B-4

Pre-Lab Quiz #4

Answer the following questions regarding the lab you are about to perform.

1. A number of different compounds are used in this lab. Which two of them pose the greatest hazard and what is/are the hazard(s)?

2. How do you adjust the flame on the bunsen burners to make them hotter?

3. What result should you look for when adding the iodine to the cornstarch?

4. What result should you look for phenolphthalein is added to the drain cleaner and washing soda?

5. Describe your practical application for this lab.

Appendix B-5

Pre-Lab Quiz #5

Answer the following questions regarding the lab you are about to perform.

1. What is the overall purpose of this lab?

2. Describe some of the practical applications of salt, as discussed in the pre-lab.

3. Why must you be careful in heating the reaction?

4. What are the two elements used in this lab and what are their hazards?

5. What visible evidence is there that the reaction is occurring?

Appendix B-6
Pre-Lab Quiz #6

Answer the following questions based on the computer pre-lab.

1. What is the main hazard posed by the silver nitrate in this lab?

(1)

2. Describe how to decant a solution.

(1)

3. What needs to be done to separate the silver from the copper wire?

(1)

4. Describe, with sufficient detail, how reactions are used in your practical application for this lab.

(1)

5. What is the overall purpose of the lab?

(1)

Appendix B-7

Pre-Lab Quiz #7

Answer the following questions regarding the lab you are about to perform.

1. Give the *complete* names of at least two of the possible salts you may be using in this lab.

2. What is the overall purpose of this lab?

3. Give the hazards for one of the salts used in this lab.

4. Distinguish between the watch glass and the evaporating dish (describe them).

5. Why is cooling the evaporating dish necessary before obtaining its mass?

Appendix B-8

Pre-Lab Quiz #8

Answer the following questions regarding the lab you are about to perform.

1. What is the overall purpose of this lab?

2. Identify by name and formula the two substances used in this lab.

3. Approximately how much of each substance is needed for the reaction?

4. Describe the appearance of the precipitate and the appearance of the filtrate (what came through the filter).

5. Describe, with sufficient detail, the practical application associated with this lab.

Appendix B-9

Pre-Lab Quiz #9

Answer the following questions regarding the lab you are about to perform.

1. What is the overall purpose of this lab?

(1)

2. How should the magnesium be set up for this lab?

(1)

3. Describe, with sufficient detail, the practical application for this lab.

(2)

4. Describe the appearance of the reaction as it occurs and how you can tell when it is complete.

(1)

Appendix C: Student Survey

Student Survey: Pre-Lab Technology Project

At this point in the year you have been exposed to a number of approaches to pre-lab requirements ranging from the in-class computer pre-labs, doing flowcharts of the lab procedure, merely reading the lab procedure, and writing your own lab procedures. Please consider each of these different methods for the first five survey questions. Use the scale (below) in answering the questions.

0	1	2	3	4	5
N/A	Much worse	A little worse	About even	A little better	Much better

1. The computer pre-labs prepared me ____ than the other methods with regard to knowing the steps involved in the labs.

2. The computer pre-labs prepared me ____ than the other methods with regard to knowing the safety issues of chemicals in the labs.

3. The computer pre-labs prepared me ____ than the other methods with regard to knowing the purpose (the "why") of the labs.

4. The computer pre-labs prepared me ____ than the other methods with regard to knowing how to do specific techniques in the labs.

5. Overall, the computer pre-labs prepared me ____ than the other methods.

Consider just the computer pre-labs for the following questions. Use the scale (below) in answering the questions.

0	1	2	3	4	5
N/A	Never	Rarely	Sometimes	Most always	Always

6. I like working with computers.

7. I did my own work on the pre-lab activities.

8. I found the video clips to be helpful in remembering specific lab steps.

9. The practical application links helped me to see how what we were doing related to the "real world".

10. I remembered the safety information when actually performing a lab.

11. List up to 3 practical applications that you can recall from the pre-labs.

BIBLIOGRAPHY

Anderson, John, *Rules of the Mind*, Hillsdale, NJ, Lawrence Erlbaum Associates, 1993

Beran, J.A. Laboratory Manual for Principles of General Chemistry, 6th ed., pgs. 1-3, John Wiley & Sons Inc., New York, New York Copyright 2000

Carmichael, L. Neal & Haines, David, Merril: Laboratory Chemistry, pgs. T3 – T56, Merrill Publishing Co., Columbus, Ohio, Copyright 1990

Chang, Ernest & Simpson, Don, "The Circle of Learning: Individual and Group Processes", Educational Policy Analysis Archives, Volume 5 Number 7, February 25, 1997, ISSN 1068-2341, web address: http://epaa.asu.edu/epaa/v5n7/, accessed July 16, 2001

Charp, Sylvia (editor), "George Middle School Increases Student Achievement With Comprehensive Learning System", T.H.E. Journal volume 29 #10, May 2002

Howard, Robert E. & Boone, William J., "What Influences Students To Enjoy Introductory Science Laboratories?", Journal of College Science Teaching; v26 n6 p383-87 May 1997

Jaeger, Dave & Weisker, Suzanne, Holt Chemistry: Visualizing Matter Lab Manual,, pgs. vii-x, Holt, Rinehart, & Winston; Austin, Texas, Copyright 1996

Kimble, Carol, Ed. D., *Policy Brief: The Impact of Technology on Learning: Making Sense of the Research* May 1999, @ www.mcrel.org/products/tech/tech.html

Kulik, James, and Kulik, C., "Effectiveness of Computer-based Instruction: An Updated Analysis," Computers in Human Behavior, 7(1-2), 75-04, 1991

Midland Public Schools, *Educational Goal and Performance Expectations: Chemistry 7413-7423*, pg. 1, 1990

Molnar, Andrew, "Technology in Education and the Next Twenty-Five Years", T.H.E. Magazine,Volume 24 Number 11, June 1997

Moss, D. M., "Bringing Bogether Technology and Students: Examining the Use of Technology in a Project-Based Class", Journal of Educational Computing Research, 22:2, pgs. 155-169, 2000

Robinson, William R., "A View of the Science Education Research Literature: Visual Aids in Laboratory Manuals Improve Comprehension", Journal of Chemical Education; v75 n3 p282-83 Mar 1998

Schackenberg, Heidi L.; Sullivan, Howard J., "Learner Ability and Learner Control in Computer Assisted Instructional Programs", In: Proceedings of Selected Research and Development Presentations at the 1997 National Convention of the Association for Educational Communications and Technology (19th, Albuquerque, NM, February 14-18, 1997); see IR 018 421.

Schenone-Stevens, M. Carla, "Reflections from the Classroom on the Effects of Computer-Assisted Instruction on the Teaching-Learning Process", Paper presented @ Annual Meeting of the National Communication Association (85th, Chicago, IL, November 4-7, 1999).

Wenglinsky, H., Does it compute? *The relationship between educational technology and student achievement in mathematics*, Princeton, NJ: Policy Information Center, Educational Testing Service, 1998

Wilbraham, A. C., et. al., Addison-Wesley Chemistry Laboratory Manual, pgs. T321 –T378, Addison-Wesley Publishing Co., Menlo-Park, CA, Copyright 1990

Wilcox, Kimberly J., "Computer Use in the Science Classroom: Proceed With Caution!", Journal of College Science Teaching, volume 26 #4 pgs. 258 – 64, Feb 1997

Withrow, Frank, "Computers in Education: A Brief History", T.H.E. Magazine, Volume 24 Number 11, June 1997