CALIFORNIA STATE UNIVERSITY, NORTH RIDGE

THE COMPUTER APPLIED TO
HIGH SCHOOL CHEMISTRY

A project submitted in partial satisfaction of the requirements for the degree of Master of Arts in

Secondary Education

by

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May, 1975
The graduate project of Robert Douglas Robinson is approved:

Committee Chairman

California State University, Northridge
January, 1975
DEDICATION

This project is dedicated to my family for their patience and encouragement.
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ABSTRACT

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by
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Computers are receiving more attention today in education, as are they in all aspects of our society. They are being used mainly for administrative purposes but are also being applied to the classroom. This project utilizes a time-shared computer to aid high school chemistry students with calculations associated with their laboratory work.

A series of programs were written in the BASIC computer language which allowed students to input their own empirical data from laboratory experiments. The computer would then give the students the percent error their data would yield and also the correct answers to computations, based on the data, that they were to perform as homework. Having the answers to these problems, the students would know if they had made an error and could make the necessary
corrections. This made it possible to avoid wasting valuable time. Also, the students would be more likely to understand the chemical principle being illustrated by the experiment.

The project was apparently successful as judged by student responses to an evaluation questionnaire. Cognitive changes were not evaluated, but expressed attitudes toward the project were favorable.

This project is now being implemented in the chemistry course at Royal High School in Simi Valley, California. It is continually being modified and revised based on the feedback given by students using it and in accordance with current educational theory.
CHAPTER 1

THE PROBLEM

Introduction

For several years, a group of secondary school teachers had been attempting to convince the Simi Valley Unified School District to purchase equipment necessary to establish a computer facility that could be used by students. Since 1965, the district had maintained a data processing center, but these facilities were not available to students. They were designed to handle only administrative functions. In January of 1974, the district purchased a mini-computer from Data Corporation. It was intended that this new equipment be used on a time-sharing basis at all levels of education.

The science departments at the two district high schools were selected to establish the time-share system and to develop procedural systems so that other departments and schools could participate in the project. Terminals were loaned by the school district data processing center to both science departments. They were connected to the computer via telephone lines. Both high schools allowed interested students computer time with which they could write their own programs. Computer programming is an
excellent use of computer facilities, but in Simi Valley involved only a small portion of the student body. If non-programming students could use programs written by someone else, the computer could reach virtually every student enrolled.

Statement of the Problem

Early in the 1960's, science teachers gathered in their respective fields to write standardized high school science textbooks. The result in chemistry was a course known as Chem-Study. The text used in the chemistry course that was used to implement this project was a revision of the original work and was titled Chemistry: Experiments and Principles (O*Conner, 1968).

The original Chem-Study course, as well as the revisions of it, was an inquiry course. That is, a major portion of the chemistry principles taught throughout the year-long course arose directly from the students' laboratory work. For this reason, it was particularly important that the students have a good understanding of the ideas that the labs were designed to illustrate.

Because this was an introductory course, the students often made errors in using calibrated laboratory equipment that was not familiar to them. They periodically would take invalid data home to use as a base for calculations designed to emphasize some principle of chemistry. These efforts were therefore in vain, for with inaccurate
data they would never reach the appropriate conclusions for the lab.

Calculations based on the original data were also sequential. That is, calculated values were often used in later computations. Therefore, if errors were made in the initial steps, later calculations would also be in error, obscuring the chemical principles involved. Not until the experiment was discussed the next day in class would the students know they had made an error. Some mechanism was needed to reduce this type of error and help prevent wasted effort.

It was felt that the computer could be used to aid the chemistry students with their calculations. Programs could be written that would check the students' data for errors and also give them the correct answers to the calculations they were to perform at home that night. They would then be able to correct errors before wasting valuable time. If this project was successful, the chemistry students would better understand the chemical processes involved, and would therefore have a greater enthusiasm for dealing with the quantitative aspects of the course.

Questions

This project attempted to answer the following questions:

Would students using the computer:

1. have a better understanding of the
chemistry principles being studied?

2. be more conscientious in their lab technique, and would they be less prone to make errors in reading calibrated laboratory instruments?

3. be aware of experimental errors through a percent error computation and would they attempt to correct the error or repeat the lab if necessary in order to obtain valid data?

4. enjoy the lab experience more in that they would know when they had solved the problem correctly?

5. have a greater enthusiasm for dealing with the quantitative aspects of the course?

6. have lessened any fear or resentment of computers?

7. check their lab technique through the percent error computation, and would they identify their own mistakes?

Limitations of the Project

The laboratories associated with the chemistry course this project was to accompany contained both
qualitative and quantitative factors. It was felt that the computer would lend itself best to the quantitative aspects of the lab. The qualitative questions usually asked the student to summarize or to explain the significance of the calculations he had performed. Programming the computer to give these answers would have been defeating the purpose of the exercise. For this reason, only quantitative aspects of each lab were to be dealt with.

Some of the laboratories that accompanied the course contained no quantitative elements to which the computer could be applied. For example, labs 1 and 2 dealt with descriptive narrations of chemical reactions, and labs 17 through 20 were concerned with the qualitative analysis of unknown ionic solutions. Because of this, only twelve of the thirty labs which the student was exposed to during the course could be adapted to computer usage.

In order to be effective, the computer usage had to be closely correlated with the calculations for the labs of the course being taught. For this reason, the project had to be written to accompany a particular course. If it were to be used to supplement another chemistry program, the project would have to be modified greatly to correlate with the different labs that would be involved.
Definition of Terms

BASIC - A computer language that allows the programmer to communicate with the computer.

COMPUTER - An electronic device that can be programmed to solve problems and give instructions.

CRT TERMINAL - A television type instrument used by the programmer to send messages and to receive messages from a computer. CRT stands for cathode ray tube, another name for a television picture tube.

DRUM - A revolving cylinder with a magnetic coating located inside the computer that is used to electronically store information.

EIGHT-HOLE TAPE - A heavy paper strip that is punched with a sequence of holes (eight across) that codes for letters, numbers and symbols. It can be used to store programs when computer storage space is limited.

FORTRAN - A computer language consisting of a mixture of English and algebraic symbols. It is the most widely used computer language.

HARD COPY - A permanent, printed copy of either a computer program itself or the result of the program (its run).
INQUIRY - A type of teaching where the main concepts being taught arise directly from the student's own work.

MINI-COMPUTER - A relatively small, inexpensive computer with limited capabilities and storage. Often these machines are adapted for a time-sharing function.

PERCENT ERROR - The degree to which an experimentally derived quantity or ratio differs from the accepted value.

PORT - One of a varying number of connections which can be made simultaneously with a computer.

PROGRAM - A sequential series of logical steps which direct a computer in solving a given problem.

SOFTWARE - Any part of a computer system that is maintained electronically as opposed to being permanently hard-wired into the system. For example, a program.

TELETYPEn TERMINAL - A typewriter type instrument used by the programmer to send messages to and to receive messages from a computer. This type of terminal provides a hard-copy of the work being done.
TIME-SHARING - A type of computer usage that alternately services each of many users so that none of them is usually aware of anyone else using the system.

Organization of the Remainder of the Project

A review of the literature is found in chapter 2. The project design and the equipment used for the project are found in chapter 3. Chapter 4 contains the computer programs written for the project and a sample run of the first program, experiment 4. Chapter 5 contains the results of the project and recommendations. A list of references follows chapter 5. Appendix A contains a sample laboratory experiment from the textbook used for the course in which this project was used (O'Conner, 1968). Appendix B is a sample student data sheet. Questionnaires A and B used to evaluate the project are found in Appendices C and D respectively.
CHAPTER 2
REVIEW OF THE LITERATURE

Computers have become an integral part of education and have influenced almost every aspect of our society. We probably couldn't conceive of running our society without the aid of computers (Hoffman, 1973). Education has been and will continue to be changed by the introduction of the computer. They are being used for many tasks in the education field. Some of the uses are budgeting, purchasing, warehousing, scheduling, counseling and attendance. This project, however, is concerned with student use of computers and their application to the classroom.

Types of Classroom Application

The computer is used in the classroom for a number of different purposes depending on, in part, the educational philosophy of the teacher. Often, those not familiar with computers in education lump all of these varied uses into one large, general category, computer-assisted instruction (CAI). However, computer application in education has been more specifically outlined.

The distinction between what is defined as computer-assisted instruction and what has become known as computer-managed instruction (CMI) is given by Cooley and
Glaser (1969):

"The computer can service classroom terminals which assist the teacher in assessing the student's capabilities and prescribing a course of instruction...On the other hand, when the computer is used by the student as a means of instruction, the term commonly used is 'computer-assisted instruction.'"

In CAI, the student interacts with the computer by means of pre-written programs. These programs are often a form of drill and practice or simulation. An example of an advanced type of CAI involves the computer being used to actually teach a new concept. When the student programs the computer himself to solve his own problems, an even more advanced level is reached. There exists a severe shortage of CAI programs at present. The probable cause is the difficulty involved in writing quality programs of this type. It is difficult to anticipate the many varied responses that students will offer in the course of an educational sequence. Some authorities in computer education consider it more difficult to develop a computer-based course than it is to compile a textbook (Suppes, 1973).

Computer-managed instruction refers to a type of computerized bookkeeping. The computer is used to store students' grades and records. It is then utilized to
branch the individual students into a sequence of materials that is custom-tailored to their needs.

Computation is such an obvious application of the computer that it tends to be overlooked (Roberts and Zirkel, 1971). Computer-assisted learning (CAL) refers to the computer being used as a programmed calculator. It is this use of the computer which this project employs.

The power of the computer as an aid to problem-solving is indicated by the success of Project LOCAL (Laboratory Program for Computer Assisted Learning) which was initiated in Massachusetts. College preparatory algebra students who were allowed to use a computer to aid them with their homework scored significantly higher on abstract reasoning and scholastic aptitude tests (Lewellen, 1971).

The BASIC Language

There are many computer languages. Of these, FORTRAN is probably the most successful (Gerrick, 1971). In this language, computations and program steps are specified by using a mixture of English and algebra. However, the beginner often finds FORTRAN inconvenient and difficult.

Recently, a computer language was developed at Dartmouth College called BASIC. The advantages of BASIC are:
1. It is easy to learn.

2. It is an algebraically oriented conversational language that is suited to chemistry calculations.

3. The programmer is given a line-by-line analysis of his program as it is being written, and errors are quickly diagnosed.

4. It is rapidly becoming a universally acceptable language.

5. It is readily available at commercial time-share terminals (Perone and Eagleston, 1971).

With BASIC, the beginning programming student need not know complex mathematical symbolism, as he would with other languages, in order to converse with the computer. The programs of this project were written in BASIC.

The Computer Used to Individualize Instruction

Traditionally, the two camps of humanism and technology have not been merged in education. Some see the introduction of computers into the classroom as a threat to the teacher and as a step to dehumanizing the educational process. Conversely, the computer offers a unique possibility for individualization in all of its educational modes. A student who is having difficulty in solving a particular problem can spend as much time as he wishes before going on to the next step. He can proceed at his
own rate without being embarrassed or slowing down his classmates. He can explore, experiment, make mistakes and try alternatives. The computer is the ideal tutor for students who have missed work. It offers an infinitely patient teacher who is available at any hour for as long as necessary (Ritzer, 1973).

The value of the computer is that, through its speed, each student can be treated as an individual. Nothing, it seems, is more dehumanizing than treating an entire classroom of students as if they were all the same. Students have varied backgrounds and have had differing exposure to the skills required to succeed in a given class. The computer affords the opportunity to treat the learner as an individual in that it responds to the needs of one student at a time. Properly programmed, the computer places emphasis on individual achievement, rather than on speed or lock-step pacing with other students (Gerald, 1967).

Motivation Factor

One of the greatest benefits of having computers in the classroom is derived from their capacity to motivate students. The reasons for this are not all that clear (Lewellen, 1971). One factor involved must be the speed with which the computer works. Students must sometimes work hours to obtain the same answers the computer
can derive in a fraction of a second. Another factor is that they immediately know if they are correct after spending the time to solve the problems by having the computer results in front of them.

Experimental work indicates that students are able to learn more in less time when the computer is properly utilized in the educational process (Lewellen, 1971). Two educationally desirable outcomes have been noted when computers are used to supplement the science curriculum:

1. Students have a better understanding of the processes which underlie the laboratories, and

2. Students acquire a greater enthusiasm for dealing with the quantitative aspects of science (Donaldson, 1972).

Economic Factor

The basic problem which limits the use of computers in education is the cost. Until recently, the enormous cost of computer facilities made them an impossibility to virtually all secondary schools (Gerrick, 1971). Even though the cost can be amortized over a long period, the initial investment is a difficult step to overcome. However, progress is being made.

At its meeting in December, 1972, the American Association for the Advancement of Science agreed by the
general consensus of its participants that computer-assisted instruction is entering a new stage with costs down to a reasonable level (Hoffman, 1973). A major factor is the advent of time-sharing. Now schools are given the choice of buying a mini-computer and establishing their own time-sharing system, or leasing low-cost time from one of many computer firms.

Computers could offer a possible solution to the economic crisis in education. The United States national investment in education exceeds $50 billion annually, and is expected to double by 1980 (Bitzer, 1973). Since the industrial revolution man has used machines to increase productivity. Computers should be no exception.

In the face of rising costs of nearly everything today, computers offer an exception. Due to advances in the technical aspects of manufacturing miniaturized electronic equipment, from personal calculators to entire computer systems, computerized education is becoming a better bargain each day.

Computers are still in their infancy. As costs decrease, they will be used more and more in the educational process. The applications are unlimited. It remains only for the ingenuity of the teacher and student to discover the true worth of computers.
Summary

Today computers are an integral part of the educational process (Hoffman, 1973). They are being used for varied administrative functions as well as by the classroom teacher. The classroom applications are of three basic types:

1. Computer-assisted Instruction (CAI) - The computer is used as a means of instruction.

2. Computer-managed Instruction (CMI) - The computer is used to prescribe individual courses of instruction.

3. Computer-assisted Learning (CAL) - The computer is used as a programmed calculator.

New programming languages such as BASIC have helped in making computers available to most people.

The computer offers a means of individualization never possible before (Bitzer, 1973). The result is a high degree of student involvement in computer projects.

Education faces an economic crisis by 1980 (Bitzer, 1973). Computers, through their great speed and efficiency, could offer the solution to that problem. It is up to the innovative educators of our society to develop and use this valuable resource.
CHAPTER 3

PROJECT DESIGN

Review of the Problem

Courses such as chemistry are heavily based on mathematics. The beginning student, therefore, can get bogged down in numerous calculations. It is necessary, however, for the student to understand the principles that these calculations illustrate. For this reason, a tool to be used by the beginning chemistry students was developed in the form of this project.

The course this project was designed to accompany was based on laboratory experimentation. Many of the important chemical principles arose directly from the laboratory exercises (i.e. reaction ratios, conservation of mass, gas laws, etc.). Yet many of the students were using measuring devices such as balances, graduated cylinders and burets for the first time. This situation led to numerous errors in the collection of empirical data. Later, when the students used the data in calculations, the discovery of the chemical principles which the lab was designed to illustrate was obscured.

Because of this predicament, a series of computer
programs were written which allowed the students to validate their own empirical data and obtain the correct answers to computations based on that data.

Description of the Project

This project applied the computer services available to the existing chemistry program. It was the intention of this project to use the computer for the task that it handles the best. That is, of giving immediate feedback on experimental values obtained in the laboratory on an individual student basis. After collecting data from laboratory experiments, the chemistry students entered their own empirical observations into the computer. The computer was programmed to give the students the results of the calculations they were to perform that night as homework. They were also given the percent error their data would yield, based on the accepted chemical principles of that lab. The students could then use the percent error computation to check their data which might be in error, or even repeat the experiment if they were not within an acceptable range of usually ten percent. In having the correct results to calculations based on their own data, the students knew before leaving the classroom whether or not their data was valid. They then would be less likely to misinterpret the chemical principles being illustrated by the experiment due to errors in calculations or invalid data. Emphasis was then focused on the method of problem
solving, rather than on the answer itself.

The computer was used as a programmed calculator to help reduce the tedium associated with lengthy hand calculations. The function of this project was not to replace the students' own calculations, but to supplement their efforts. Students using this program were instructed to prepare the report for the lab as usual, and to use values obtained from the computer to check the results of their own problem solving. This program was to serve solely as a supplemental aid, and was not intended to replace any part of the existing course.

It was not necessary for the students using the programs of this project to be familiar with the BASIC computer language. Further, it was not necessary for them to have had electronics in order to understand the operation of the computer. The only instruction that had to be given was a short lesson in how to initiate a run of the program, type in their data, correct mistakes in typing and return the carriage to the next line.

All students enrolled in the regular two-semester chemistry program at Royal High School participated in the project. The computer programs were written in the spring semester of the 1973-74 school year. Four of the twelve programs written were used at the end of that school year. The remaining eight programs were used by the chemistry students enrolled for the 1974-75 school year.
Because the project was being run on a CRT terminal with no hard-copy capability, students had to copy the values given by the computer from the terminal screen. This caused a waiting line to form by the terminal. To help alleviate this problem, student worksheets were developed to accompany each program (see Appendix B). The worksheets contained everything that was printed on the screen with the exception of the actual calculated values. The student then just had to fill in the blanks.

Evaluation

The project was evaluated by a questionnaire given to the students who were enrolled in the chemistry course for the 1973-74 school year (see Appendix C). These students had used the last four programs (experiments 25, 26, 27 and 29). The remainder of the programs were evaluated by a revised questionnaire given to the chemistry students enrolled for the 1974-75 school year (see Appendix D). The results of both of these questionnaires are found in Chapter 4.

Equipment

The system on which this project was run consists of a Datum Corporation mini-computer, the T-S 70, located at the School District's central offices, and a Hazeltine 2000 CRT terminal, located in the chemistry classroom.
The Datum T-S 70 had 16 ports of which five were dedicated to polled lines for administrative use (records, attendance, etc.). Six additional ports were made inactive in order to make available additional storage space. The remaining five ports were available on a time-sharing basis for students at the two District high schools. The computer had a time-sharing drum with a core capacity of 32K, or 9226 words. 8K of this capacity was dedicated to the polled ports. Students communicated with the computer via a Hazeltine CRT over telephone lines. The terminal was set at a baud rate of 300. A Prentice Corporation DC-22 data coupler was used to connect the terminal to the computer.

The Datum T-S 70 mini-computer was purchased at a cost of $35,000 and the Hazeltine 2000 terminals cost approximately $2000. The cost of establishing a system for a project such as this one, however, varies considerably.

Programs were written in the BASIC language, developed at Dartmouth College. These programs correlated with the laboratory exercises that accompany the course text, Chemistry: Experiments and Principles, O'Conner, et. al. (see Appendix B for a sample laboratory exercise). After completing a laboratory, the students input the numerical data they collected via the Hazeltine CRT terminal. The computer then processed this data through
the BASIC programs and gave the students the correct answers to the calculations they were to complete that night as homework. The programs also computed the validity of the data through a percent error calculation. By this method, the student knew when he was working the problems at home whether or not he was doing them correctly. Also the student knew before he left the class that his data was valid.

Due to a relatively small time-sharing drum, storage on the computer system was limited and programs had to be saved on punched paper tape. Preceeding each chemistry lab, the appropriate tape was then read into the system, saved and then dumped to make room for the next program. The teletype terminal used for entering the tapes was the master terminal for the system and was located at the School District's Data Processing Center along with the computer itself.
CHAPTER 4

THE COMPUTER PROGRAMS

This project consisted of twelve computer programs that allowed students to input their laboratory data to determine its validity and to obtain the correct answers to calculations based on that data. The programs were designed to correlate with the laboratory exercises of the text, Chemistry: Experiments and Principles (O'Conner, 1968). A sample exercise from the student laboratory manual is included for the first program, experiment 4. The programs were written in the BASIC language.

The major difficulty with the project was that each student had to wait in line in order to use the computer terminal. Because of the type of terminal that was used for the project, a CRT, the problem was even more significant than if a teletype had been used. This was because each student had to copy all information given by the computer from the CRT screen. To help alleviate this problem student worksheets were designed for each program. An example of a worksheet is included for experiment 4 (see Appendix B).

A sample run of the first program is given. By examining the programs, one can see that the student was
given one of several comments on his lab technique, depending upon the magnitude of his percent error. Each program instructed the student that he must show how the problems were solved in order to receive credit for the lab. Thus, emphasis was placed on the method of problem solving rather than on the answer itself.

The programs follow:
10 PRINT "EXPERIMENT 4 - WEIGHING AN OBJECT IMMERSED IN TWO DIFFERENT FLUIDS"
20 PRINT "TYPE IN YOUR OWN DATA FROM THE LABORATORY"
30 PRINT "DO NOT INCLUDE THE UNITS"
40 PRINT "STUDENT INPUT OF DATA"
50 PRINT "CYLINDER NUMBER 1"
60 PRINT "MASS IN AIR";
70 INPUT M1
80 PRINT "MASS IN WATER";
90 INPUT M2
100 PRINT "VOLUME OF WATER IN GRADUATE";
110 INPUT V1
120 PRINT "VOLUME OF WATER + CYLINDER";
130 INPUT V2
140 PRINT "CYLINDER NUMBER 2"
150 PRINT "MASS IN AIR";
160 INPUT M3
170 PRINT "MASS IN WATER";
180 INPUT M4
190 PRINT "VOLUME OF WATER IN GRADUATE";
200 PRINT "VOLUME OF WATER + CYLINDER";
210 PRINT "CYLINDER NUMBER 2"
220 PRINT "MASS IN AIR";
230 INPUT M3
240 PRINT "MASS IN WATER";
250 PRINT "VOLUME OF WATER IN GRADUATE";
260 PRINT "VOLUME OF WATER + CYLINDER";
270 PRINT "CYLINDER NUMBER 2"
280 PRINT "MASS IN AIR";
290 INPUT M3
300 PRINT "MASS IN WATER";
310 PRINT "VOLUME OF WATER IN GRADUATE";
320 PRINT "VOLUME OF WATER + CYLINDER";
330 PRINT "***********************************************"
340 PRINT "PROCESSING THE DATA"
350 PRINT "***********************************************"
360 LET M5=M1-M2
370 LET M6=M3-M4
380 PRINT "1. MASS DIFFERENCE= M5; M6; "
390 PRINT "2. VOLUME= V5; V6; "
400 PRINT "4. MASS OF WATER DISPLACED= V5; V6; "
410 LET R1=V5/M5
420 LET R2=V6/M6
430 PRINT "5. VALUE OF RATIO= R1, R2"
440 LET D1=V5*1.18E-03
450 PRINT "***********************************************"
510 LET D2=V6*1.18E-03
520 LET M7=M1+D1
530 LET M8=M3+D2
540 PRINT " 8. MASS IN A VACUUM= " ,M7,"G" ,M8,"G"
550 LET P1=(1-R1)*100
560 IF P1>0 GOTO 580
570 LET P1=(R1-1)*100
580 LET P2=(1-R2)*100
590 IF P2>0 GOTO 610
600 LET P2=(P2-1)*100
610 PRINT " PERCENT ERROR= " ,P1,"%" ,P2,"%"
620 PRINT
630 LET R=(P1+P2)/2
640 IF R<=5 GOTO 680
650 IF R<=10 GOTO 700
660 IF R>=20 GOTO 740
670 IF R>=15 GOTO 760
680 PRINT "GOOD JOB! YOUR LAE TECHNIQUE SEEMS TO BE EXCELLENT."
690 GOTO 700
700 PRINT "PRETTY GOOD. YOUR ARE WITHIN 10%"
710 GOTO 720
720 PRINT "FAIRLY HIGH PERCENT ERROR. RECHECK YOUR DATA."
730 GOTO 740
740 PRINT "WOW!! ARE YOU SURE YOU KNOW HOW TO READ A BALANCE? RECHECK"
750 PRINT " YOUR DATA."
760 PRINT
770 PRINT "COPY THESE VALUES DOWN IN YOUR LAEORATORY NOTEBOOK SO THAT"
780 PRINT "YOU CAN CHECK YOUR ANSWERS TONIGHT. REMEMBER, YOU MUST"
790 PRINT "SHOW HOW YOU GOT THE ANSWERS TO RECEIVE CREDIT!!!"
800 END
RUN

EXPERIMENT 4 - WEIGHING AN OBJECT IMMERSED IN TWO DIFFERENT FLUIDS

TYPE IN YOUR OWN DATA FROM THE LABORATORY
DO NOT INCLUDE THE UNITS

CYLINDER NUMBER 1
MASS IN AIR? 67.80
MASS IN WATER? 61.80
VOLUME OF WATER IN GRADUATE? 17.4
VOLUME OF WATER + CYLINDER? 23.5

CYLINDER NUMBER 2
MASS IN AIR? 16.20
MASS IN WATER? 10.00
VOLUME OF WATER IN GRADUATE? 18.7
VOLUME OF WATER + CYLINDER? 24.6

******************************************************
PROCESSING THE DATA
******************************************************

<table>
<thead>
<tr>
<th>CYL #1</th>
<th>CYL #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. MASS DIFFERENCE= 6 G</td>
<td>6.2 G</td>
</tr>
<tr>
<td>2. VOLUME= 6.1 ML</td>
<td>5.9 ML</td>
</tr>
<tr>
<td>4. MASS OF WATER DISPLACED= 6.1 G</td>
<td>5.9 G</td>
</tr>
<tr>
<td>5. VALUE OF RATIO= 1.01666</td>
<td>951612</td>
</tr>
<tr>
<td>8. MASS IN A VACUUM= 67.8071 G</td>
<td>16.2069 G</td>
</tr>
<tr>
<td>PERCENT ERROR= 1.666 %</td>
<td>4.8388 %</td>
</tr>
</tbody>
</table>

GOOD JOB! YOUR LAB TECHNIQUE SEEMS TO BE EXCELLENT.

COPY THESE VALUES DOWN IN YOUR LABORATORY NOTEBOOK SO THAT YOU CAN CHECK YOUR ANSWERS TONIGHT. REMEMBER, YOU MUST SHOW HOW YOU GOT THE ANSWERS TO RECEIVE CREDIT!!!
10 PRINT "EXPERIMENT 5 - THE MASS OF EQUAL VOLUMES OF GASES"
20 PRINT
30 PRINT "TYPE IN YOUR OWN DATA FROM THE LABORATORY"
40 PRINT " DO NOT INCLUDE THE UNITS"
50 PRINT
60 REM STUDENT INPUT OF DATA
70 PRINT "MASS OF BAG ASSEMBLY";
80 INPUT M1
90 PRINT
100 PRINT "MASS OF BAG ASSEMBLY + OXYGEN";
110 INPUT M2
120 PRINT
130 PRINT "MASS OF BAG ASSEMBLY + CARBON DIOXIDE";
140 INPUT M3
150 PRINT
160 PRINT "MASS OF BAG ASSEMBLY + NATURAL GAS";
170 INPUT M4
180 PRINT
190 PRINT "VOLUME OF THE BAG (IN LITERS)";
200 INPUT V1
210 PRINT
220 PRINT "ROOM TEMPERATURE";
230 INPUT T1
240 PRINT
250 PRINT "ROOM PRESSURE";
260 INPUT P1
270 PRINT
280 PRINT
290 PRINT "*************************************************************
300 PRINT " PROCESSING THE DATA"
310 PRINT "*************************************************************
320 PRINT
330 PRINT "", "", "OXYGEN", "CARBON DIOXIDE", "NAT. GAS"
340 LET A1=M2-M1
350 LET A2=M3-M1
360 LET A3=M4-M1
370 PRINT "1. APP. MASS OF GAS =", A1; "G", A2; "G", A3; "G"
380 REM *****
390 REM INSTRUCTOR MUST PROGRAM DENSITY OF AIR, LINE 530
400 REM *****
410 LET D=1.17
420 LET E=V1*P1
430 PRINT "2. MASS OF AIR DISPL. =", E; "G", E; "G", E; "G"
440 LET C1=E+A1
450 LET C2=E+A2
460 LET C3=E+A3
470 PRINT "3. ACTUAL MASS OF GAS =", C1; "G", C2; "G", C3; "G"
480 LET R1=C2/C1
490 LET R2=C3/C1
500 PRINT "5. RATIO OF CO2 TO O2 =", R1
510 PRINT " RATIO OF NAT. GAS TO O2 ="; R2
520 LET P1 = (R1 - 1.38) / 1.38 * 100
530 IF P1 > 0 GOTO 550
540 LET P1 = (1.38 - R1) / 1.38 * 100
550 LET P2 = (R2 - .634) / .634 * 100
560 IF P2 > 0 GOTO 580
570 LET P2 = (.634 - R2) / .634 * 100
580 LET P = (P1 + P2) / 2
590 PRINT " PERCENT ERROR ="; P; 
600 IF P <= 5 GOTO 650
610 IF P <= 10 GOTO 670
620 IF P >= 15 GOTO 700
630 IF P >= 20 GOTO 730
640 GOTO 740
650 PRINT "VERY GOOD JOB!!!"
660 GOTO 740
670 PRINT "PRETTY GOOD. YOUR PERCENT ERROR IS WITHIN AN ACCEPTABLE" RANGE."
680 GOTO 740
700 PRINT "FAIRLY HIGH PERCENT ERROR. ARE YOU SURE OF ALL YOUR MEASUREMENTS?"
710 GOTO 740
720 PRINT "WHAT WENT WRONG? YOU SHOULD RECHECK YOUR DATA!"
730 PRINT "COPY THESE VALUES DOWN IN YOUR LABORATORY NOTEBOOK SO THAT YOU CAN CHECK YOUR ANSWERS TONIGHT. REMEMBER, YOU MUST SHOW HOW YOU GOT THE ANSWERS TO RECEIVE CREDIT!!!"
740 PRINT
750 PRINT
760 PRINT
770 PRINT
780 END
10 PRINT "EXPERIMENT 6 - IRON - COPPER SULFATE REACTION"
20 PRINT
30 PRINT "TYPE IN YOUR OWN DATA FROM THE LABORATORY"
40 PRINT " DO NOT INCLUDE THE UNITS"
50 PRINT
60 REM STUDENT INPUT OF DATA
70 PRINT "MASS OF EMPTY BEAKER";
80 INPUT M1
90 PRINT
100 PRINT "MASS OF WEIGHING PAPER";
110 INPUT M2
120 PRINT
130 PRINT "MASS OF IRON FILINGS PLUS WEIGHING PAPER";
140 INPUT M3
150 PRINT
160 PRINT "MASS OF PRODUCT (DRY SOLID) PLUS BEAKER";
170 INPUT M4
180 PRINT
190 PRINT
200 PRINT "******************************************************************************
210 PRINT " PROCESSING THE DATA"
220 PRINT "******************************************************************************
230 PRINT
240 LET M5=M4-M1
250 PRINT 1. MASS OF PRODUCT=";M5;"GRAMS"
260 LET N1=(M3-M2)/55.8
270 PRINT 2. MOLES OF IRON=";N1;"MOLES"
280 LET N2=M5/63.5
290 PRINT 3. MOLES OF COPPER PRODUCED=";N2;"MOLES"
300 LET R=N1/N2
310 PRINT 4. MOLES FE/ MOLES CU=";R
320 LET P=(1-R)*100
330 IF P>0 GOTO 350
340 LET P=(R-1)*100
350 PRINT " PERCENT ERROR=";P;"%"
360 IF P<=5 GOTO 400
370 IF P<=10 GOTO 420
380 IF P>=20 GOTO 460
390 IF P>=15 GOTO 440
400 PRINT "WWWWWWWWWW!!!! A SUPERCHEMIST!!"
410 GOTO 470
420 PRINT "YOU'RE WITHIN 10% GOOD JOB!!"
430 GOTO 470
440 PRINT "FAIRLY HIGH PERCENT ERROR. RECHECK YOUR DATA."
450 GOTO 470
460 PRINT "WOW!! YOU MUST HAVE HAD DIRTY GLASSWARE! RECHECK YOUR DATA."
470 GOTO
480 PRINT "COPY THESE VALUES DOWN IN YOUR LABORATORY NOTEBOOK SO THAT"
490 PRINT "YOU CAN CHECK YOUR ANSWERS TONIGHT. REMEMBER, YOU MUST"
500 PRINT "SHOW HOW YOU GOT THE ANSWERS TO RECEIVE CREDIT!!!"
600 END
10 PRINT "EXPERIMENT 7 - COPPER - SILVER NITRATE REACTION"
20 PRINT
30 PRINT "TYPE IN YOUR OWN DATA FROM THE LABORATORY"
40 PRINT "DO NOT INCLUDE THE UNITS"
50 PRINT
60 REM STUDENT INPUT OF DATA
70 PRINT "MASS OF CLEAN, DRY 100 ML BEAKER";
80 INPUT M1
90 PRINT
100 PRINT "MASS OF VIAL, CAP AND SILVER NITRATE";
110 INPUT M2
120 PRINT
130 PRINT "MASS OF EMPTY VIAL AND CAP";
140 INPUT M3
150 PRINT
160 PRINT "MASS OF THE COILED WIRE BEFORE REACTION";
170 INPUT M4
180 PRINT
190 PRINT "MASS OF THE COILED COPPER WIRE AFTER REACTION";
200 INPUT M5
210 PRINT
220 PRINT "MASS OF THE BEAKER PLUS SILVER CRYSTALS";
230 INPUT M6
240 PRINT
250 PRINT
260 PRINT "*******************************************************************************/
270 PRINT " PROCESSING THE DATA"
280 PRINT "*******************************************************************************/
290 PRINT
300 LET D1=M4-M5
310 PRINT " 1. CHANGE IN MASS OF COPPER WIRE=";D1;"GRAMS"
320 LET N1=D1/63.5
330 PRINT " 2. MOLES OF COPPER REACTED=";N1;"MOLES"
340 LET D2=M6-M1
350 PRINT " 3. MASS OF SILVER OBTAINED=";D2;"GRAMS"
360 LET N2=D2/108
370 PRINT " 4. MOLES OF SILVER PRODUCED=";N2;"MOLES"
380 LET R1=N2/N1
390 PRINT " 5. MOLES AG/MOLES CU=";R1
400 LET N3=(N2-N3)/170
410 PRINT " 6. MOLES OF SILVER NITRATE USED=";N3;"MOLES"
420 LET R2=N2/N3
430 PRINT " 7. MOLES AG/MOLES AGNO3=";R2
440 LET A1=N1*6.02E+23
450 PRINT " 9. ATOMS OF COPPER REMOVED=";A1;"ATOMS"
460 LET A2=N2*6.02E+23
470 PRINT " 10. ATOMS OF SILVER FORMED=";A2;"ATOMS"
480 LET P1=(R1-2)/2*100
490 IF P1>0 GOTO 510
500 LET P1=(2-R1)/2*100
510 LET P2=(R2-1)*100
520 IF P2>=0 GOTO 540
530 LET P2=(1-P2)*100
540 LET P=(P1+P2)/2
550 PRINT " PERCENT ERROR=";P;"%"
560 PRINT
570 IF P<=5 GOTO 620
580 IF P<=10 GOTO 640
590 IF P>15 GOTO 660
600 PRINT "FAIRLY HIGH PERCENT ERROR. RECHECK YOUR DATA."
610 GOTO 670
620 PRINT "WOW!! A SUPERCHEMIST! CONGRATULATIONS!"
630 GOTO 670
640 PRINT "O.K. YOU ARE WITHIN 10%"
650 GOTO 670
660 PRINT "OOPS!! WHAT WENT WRONG? RECHECK YOUR DATA."
670 PRINT
680 PRINT "COPY THESE VALUES DOWN IN YOUR LABORATORY NOTEBOOK SO THAT"
690 PRINT "YOU CAN CHECK YOUR ANSWERS TONIGHT. REMEMBER, YOU MUST"
700 PRINT "SHOW HOW YOU GOT THE ANSWERS TO RECEIVE CREDIT!!!"
710 END
10 PRINT "EXPERIMENT 8 - CONSERVATION OF MASS DURING A CHEMICAL CHANGE"
20 PRINT
30 PRINT "TYPE IN YOUR OWN DATA FROM THE LABORATORY"
40 PRINT "DO NOT INCLUDE THE UNITS"
50 PRINT
60 PRINT "MASS OF BEAKER #1 FROM EXP. 7";
70 INPUT M1
80 PRINT
90 PRINT "MASS OF SILVER NITRATE USED IN EXP. 7";
100 INPUT M2
110 PRINT
120 PRINT "MASS OF SILVER FROM EXP. 7";
130 INPUT M3
140 PRINT
150 PRINT "MASS OF BEAKER #1 + AgNO3(PART 1)";
160 INPUT M4
170 PRINT
180 PRINT "MASS OF BEAKER #1 + FILTER PAPER + AGCL";
190 INPUT M5
200 PRINT
210 PRINT "MASS OF BEAKER #2";
220 INPUT M6
230 PRINT
240 PRINT "MASS OF BEAKER #2 + NaCl";
250 INPUT M7
260 PRINT
270 PRINT "MASS OF ONE FILTER PAPER";
280 INPUT M8
290 PRINT
300 PRINT "MASS OF BEAKER #2 + RESIDUE";
310 INPUT M9
320 PRINT
330 PRINT
340 PRINT "*****************************************************************************"
350 PRINT "PROCESSING THE DATA"
360 PRINT "*****************************************************************************"
370 PRINT
380 LET G1=M4-M1
390 LET G2=M7-M6
400 LET G3=M5-M1-M8
410 LET G4=M9-M6
420 LET N1=M3/108
430 LET N2=M2/170
440 LET N3=G1/170
450 LET N4=G2/58.5
460 LET N5=G3/143
470 PRINT "1. " " MASS(G)" " MOLES"
480 PRINT " AG FROM EXP. 7 " " M3,N1"
490 PRINT " AGNO3 USED IN EXP. 7 " " M2,N2"
500 PRINT " AGNO3 PRODUCED IN EXP. 8 " " G1,N3"
510 PRINT " NACL ";G2,N4
520 PRINT " AGCL IN BEAKER #1 ";G3,N5
530 PRINT " RESIDUE IN BEAKER #2 ";G4,"----------"
540 LET R1=(G3+G4)/(G1+G2)
550 PRINT " 3. VALUE OF RATIO =";R1
560 LET XI=R1
570 IF XI>=1 GOTO 590
580 LET XI=1/R1
590 LET R2=N1/N3
600 LET R3=N1/N5
610 PRINT " 4. MOLES AG/ MOLES AGNO3(EXP. 8) =";R2
620 PRINT " MOLES AG/ MOLES AGCL =";R3
630 LET X2=R2
640 IF X2>=1 GOTO 660
650 LET X2=1/R2
660 LET X3=R3
670 IF X3>=1 GOTO 690
680 LET X3=1/R3
690 LET p=N5/N2*100
700 PRINT " 5. PERCENT SILVER RECLAIMED =";P;"%"
710 LET X4=P/100
720 IF X4>=1 GOTO 740
730 LET X4=100/P
740 LET y=(X1+X2+X3+X4)/4
750 LET z=(1-y)*100
760 IF z>0 GOTO 780
770 LET z=(y-1)*100
780 PRINT " PERCENT ERROR=";z;"%"
790 IF z<=5 GOTO 830
800 IF z<=10 GOTO 850
810 IF z>=20 GOTO 890
820 IF z>=15 GOTO 870
830 PRINT "WHOOPPEEEE! YOU GET THE BRILLIANT CHEMIST AWARD!"
840 GOTO 910
850 PRINT "VERY GOOD! YOUR LAE TECHNIQUE SEEMS TO BE GOOD."
860 GOTO 910
870 PRINT "FAIRLY LOW YIELD. CHECK YOUR DATA."
880 GOTO 910
890 PRINT "OGPS!!! MAYBE ALL THAT STUFF IN THE BEAKER WASN'T SILVER."
900 PRINT " CHECK YOUR DATA FOR ERRORS."
910 PRINT
920 PRINT "COPY THESE VALUES DOWN IN YOUR LABORATORY NOTEBOOK SO THAT"
930 PRINT "YOU CAN CHECK YOUR ANSWERS TONIGHT. REMEMBER, YOU MUST"
940 PRINT "SHOW HOW YOU GOT THE ANSWERS TO RECEIVE CREDIT!!!"
950 END
10 PRINT "EXPERIMENT 11 - THE REACTION OF Mg WITH HCL"
20 PRINT
30 PRINT "TYPE IN YOUR OWN DATA FROM THE LABORATORY"
40 PRINT "DO NOT INCLUDE THE UNITS"
50 PRINT
60 REM STUDENT INPUT OF DATA
70 PRINT "MASS OF Mg RIBBON (IN G/M)=";
80 INPUT M1
90 PRINT
100 PRINT "LENGTH OF Mg RIBBON USED (IN CM)=";
110 INPUT L1
120 PRINT
130 PRINT "VOLUME OF H2 + H2O VAPOR (IN ML)=";
140 INPUT V1
150 PRINT
160 PRINT "TEMPERATURE OF WATER BATH=";
170 INPUT T1
180 PRINT
190 PRINT "ROOM TEMPERATURE=";
200 INPUT T2
210 PRINT
220 PRINT "ROOM PRESSURE=";
230 INPUT P1
240 PRINT
250 PRINT "VAPOR PRESSURE OF WATER (FROM TABLE)=";
260 INPUT P2
270 PRINT
280 PRINT
290 PRINT "*****************************************************************************
300 PRINT " PROCESSING THE DATA"
310 PRINT "*****************************************************************************
320 PRINT
330 LET M2=L1*1E-02*M1
340 PRINT "    1. MASS OF Mg USED=";M2;" GRAMS"
350 LET N1=M2/24.3
360 PRINT "    2. MOLES OF Mg USED=";N1;" MOLES"
370 LET P3=P1-P2
380 PRINT "    3. PARTIAL PRESSURE OF H2 GAS=";P3;" MM HG"
390 LET V2=V1*(P3/760)
400 PRINT "    4. VOLUME OF DRY H2 AT 1 ATM=";V2;" ML"
410 LET V3=V2/N1
420 LET V4=V3/1000
430 PRINT "    5. VOL OF DRY H2 @ RM TEMP & 1 ATM/1 MOLE Mg=";V3;" ML"
440 PRINT "    6. MOLAR VOL OF H2 @ RM TEMP & 1 ATM=";V4;" L/TEPS"
450 LET D1=2/V4
460 PRINT "    7. DENSITY OF H2 GAS=";D1;" G/L"
470 IF T2<21 GOTO 530
480 IF T2=21 GOTO 550
490 IF T2=22 GOTO 570
500 IF T2=23 GOTO 590
510 IF T2=24 GOTO 610
520 IF T2>=25 GOTO 630
530 LET V=24.04
540 GOTO 640
550 LET V=24.12
560 GOTO 640
570 LET V=24.21
580 GOTO 640
590 LET V=24.28
600 GOTO 640
610 LET V=24.37
620 GOTO 640
630 LET V=24.45
640 LET P=(V4-V)*100
650 IF P>0 GOTO 670
660 LET P=(V-V4)*100
670 PRINT " PERCENT ERROR=";P;"%
680 PRINT
690 IF P<=10 GOTO 740
700 IF P<=15 GOTO 760
710 IF P>=25 GOTO 780
720 PRINT "YOU SHOULD BE WITHIN 15%. RECHECK YOUR DATA."
730 GOTO 800
740 PRINT "YOU RECEIVE THE SUPERCHEMIST AWARD!! CONGRATULATIONS!"
750 GOTO 800
760 PRINT "VERY GOOD! YOUR DATA IS ACCEPTABLE."
770 GOTO 800
780 PRINT "WOW! SOMETHING WENT WRONG. SEE YOUR TEACHER!"
790 GOTO 840
800 PRINT
810 PRINT "COPY THESE VALUES DOWN IN YOUR LABORATORY NOTEBOOK SO THAT"
820 PRINT "YOU CAN CHECK YOUR ANSWERS TONIGHT. REMEMBER, YOU MUST SHOW"
830 PRINT "HOW THE ANSWERS ARE OBTAINED IN ORDER TO RECEIVE CREDIT!"
840 END
10 PRINT "EXPERIMENT 13 - ENERGY NEEDED TO MELT ICE"
20 PRINT
30 PRINT "TYPE IN YOUR OWN DATA FROM THE LABORATORY"
40 PRINT " DO NOT INCLUDE THE UNITS"
50 REM STUDENT INPUT OF DATA
60 PRINT "VOLUME OF WARM WATER USED=";
70 INPUT V1
80 PRINT
90 PRINT "INITIAL TEMPERATURE OF WATER=";
100 INPUT T1
110 PRINT
120 PRINT "EQUILIBRIUM TEMPERATURE OF ICE-WATER SYSTEM=";
130 INPUT T2
140 PRINT
150 PRINT "FINAL VOLUME OF WATER=";
160 INPUT V2
170 PRINT
180 PRINT
200 PRINT "**********************************************************************"
210 PRINT " PROCESSING THE DATA"
220 PRINT "**********************************************************************"
230 PRINT
240 LET M1=V2-V1
250 PRINT " 1. MASS OF ICE MELTED=";M1;" GRAMS"
260 LET T3=T1-T2
270 PRINT " 2. CHANGE IN TEMPERATURE OF WATER=";T3;" DEGREES CELCIUS"
280 LET E1=T3*V1
290 LET E2=E1/1000
300 PRINT " 3. ENERGY RELEASED BY WATER=";E1;" CALORIES, OR";E2;" KILOCALORIES"
310 PRINT
320 LET E3=E1/M1
330 PRINT " 4. ENERGY REQUIRED TO MELT ONE G ICE=";E3;" CAL/G"
340 LET E4=E3*18
350 LET E5=E4/1000
360 PRINT " 5. ENERGY REQUIRED TO MELT 1 G ICE=";E4;" CAL/MOLE, OR";E5;" KCAL/MOLE"
370 PRINT
380 LET P=(E5-1.44)/1.44*100
390 IF P>0 GOTO 430
400 LET P=(1.44-E5)/1.44*100
410 PRINT " PERCENT ERROR=";P;"%"
420 PRINT
430 IF P<=5 GOTO 470
440 IF P<=10 GOTO 490
450 IF P>=20 GOTO 530
460 IF P>10 GOTO 510
470 PRINT "VERY GOOD JOB! YOU GET A GOLD STAR ON THIS LAB!"
480 GOTO 550
490 PRINT "GOOD WORK! YOUR EXPERIMENTAL VALUE IS ACCEPTABLE."
500 GOTO 550
510 PRINT "YOUR ERROR IS HIGH. REPEAT THE LAB IF TIME PERMITS."
520 GOTO 550
530 PRINT "WOW! WHAT HAPPENED? REPEAT THE LAB."
540 GOTO 590
550 PRINT
560 PRINT "COPY THESE VALUES DOWN IN YOUR LABORATORY NOTEBOOK SO THAT"
570 PRINT "YOU CAN CHECK YOUR ANSWERS TONIGHT. REMEMBER, YOU MUST"
580 PRINT "SHOW HOW YOU GOT THE ANSWERS TO RECEIVE CREDIT!!!"
590 END
10 PRINT "EXPERIMENT 14 - ENERGY OF CRYSTALLIZATION (SODIUM"
20 PRINT "THIOSULFATE PENTAHYDRATE)"
30 PRINT
40 PRINT "TYPE IN YOUR OWN DATA FROM THE LABORATORY"
50 PRINT "DO NOT INCLUDE THE UNITS"
60 PRINT
70 REM  STUDENT INPUT OF DATA
80 PRINT "VOLUME OF WATER USED IN CALORIMETER=";
90 INPUT V1
100 PRINT
110 PRINT "INITIAL TEMPERATURE OF WATER=";
120 INPUT T1
130 PRINT
140 PRINT "FINAL TEMPERATURE OF WATER=";
150 INPUT T2
160 PRINT
170 PRINT "MASS OF NA2S2O3*5H2O USED=";
180 INPUT M1
190 PRINT
200 PRINT
210 PRINT "*************************************************************"  
220 PRINT "PROCESSING THE DATA"
230 PRINT "*************************************************************"
240 PRINT
250 LET E1=V1*(T2-T1)/M1
260 PRINT "E REL. EY NA2S2O3*5H2O AS IT SOLIDIFIES=";E1;"CAL/G"
270 LET E2=E1/1000*248
280 PRINT "OR ";E2;"KCAL/MOLE"
290 PRINT
300 LET P=(E2-11.85)/11.85*100
310 IF P>0 GOTO 330
320 LET P=(11.85-E2)/11.85*100
330 PRINT "PERCENT ERROR=";P;"%"
340 PRINT
350 IF P<=5 GOTO 400
360 IF P<=10 GOTO 420
370 PRINT "YOUR DATA IS NOT ACCEPTABLE. RECHECK YOUR PROCEDURE AND"
380 PRINT "DATA, AND SEE YOUR TEACHER FOR HELP."
390 GOTO 470
400 PRINT "SUPERIOR WORK!! PAT YOURSELF ON THE BACK!"
410 GOTO 430
420 PRINT "YOU ARE WITHIN 10%. GOOD JOB!"
430 PRINT
440 PRINT "COPY THESE VALUES DOWN IN YOUR LABORATORY NOTEBOOK SO THAT"
450 PRINT "YOU CAN CHECK YOUR ANSWERs TONIGHT. REMEMBER, YOU MUST"
460 PRINT "SHOW HOW YOU GOT THE ANSWERS TO RECEIVE CREDIT!!!"
470 END
10 PRINT "EXPERIMENT 25 - ENERGY OF COMBUSTION"
20 PRINT
30 PRINT "TYPE IN YOUR OWN DATA FROM THE LABORATORY"
40 PRINT " DO NOT INCLUDE THE UNITS"
50 PRINT
60 REM STUDENT INPUT OF DATA
70 PRINT "INITIAL MASS OF CANDLE + LID"
80 INPUT M1
90 PRINT
100 PRINT "INITIAL TEMPERATURE OF WATER"
110 INPUT T1
120 PRINT
130 PRINT "FINAL TEMPERATURE OF WATER"
140 INPUT T2
150 PRINT
160 PRINT "FINAL MASS OF CANDLE + LID (BE SURE TO INCLUDE ANY"
DRIPPINGS FORMED)"
170 PRINT " DO NOT INCLUDE THE UNITS"
180 INPUT M2
190 PRINT
200 PRINT "VOLUME OF WATER HEATED (IN ML)"
210 INPUT V
220 PRINT
230 PRINT
240 PRINT "************************************************************************
250 PRINT " RESULTS OF PROCESSING THE DATA"
260 PRINT "************************************************************************
270 PRINT
280 LET M3=M1-M2
290 PRINT " 1. MASS OF CANDLE BURNED = ";M3;"G"
300 PRINT " 2. MASS OF WATER HEATED = ";V;"G"
310 LET T3=T2-T1
320 PRINT " 3. TEMPERATURE CHANGE OF WATER = ";T3;"DEGREES CELCIUS"
330 LET H1=V*T3
340 LET H2=H1/1000
350 PRINT " 4. HEAT REQUIRED TO WARM THE WATER = ";H1;"CALORIES"
OR";H2;"KILOCALORIES"
360 PRINT " 5. HEAT OF COMBUSTION PER ONE GRAM OF WAX = "
400 PRINT " 6. HEAT OF COMBUSTION PER ONE GRAM OF WAX = "
410 LET H5=352*H4
420 PRINT " 7. MOLAR HEAT OF COMBUSTION = ";H5;"KCAL/MOLE"
430 LET P=(H5-2400)*100/2400
440 IF P<0 GOTO 460
450 GOTO 480
460 LET P1=(2400-H5)*100/2400
470 LET P=P1
480 PRINT " 8. PERCENT ERROR = ";P;"%"
490 IF P<=5 GOTO 540
500 IF P<=10 GOTO 560
510 IF P>=50 GOTO 600
520 IF P>=25 GOTO 580
530 GOTO 610
540 PRINT "WAY TO HANG IN THERE, SUPERCHEMIST!!"
550 GOTO 610
560 PRINT "YOU'RE WITHIN 10% - - GOOD JOE!"
570 GOTO 610
580 PRINT "COULD HAVE BEEN BETTER. WAS YOUR DATA TYPED IN CORRECTLY?"
590 GOTO 610
600 PRINT "EL BOMB-O!!! WHAT WENT WRONG? RECHECK YOUR DATA."
610 PRINT
620 PRINT "COPY THESE VALUES DOWN IN YOUR LABORATORY NOTEBOOK SO THAT"
630 PRINT "YOU CAN CHECK YOUR ANSWERS TONIGHT. REMEMBER, YOU MUST"
640 PRINT "SHOW HOW YOU GOT THE ANSWERS TO RECEIVE CREDIT!!!"
650 END
10 PRINT "EXPERIMENT 26 - HEAT OF REACTION"
20 PRINT
30 PRINT "TYPE IN YOUR OWN DATA FROM THE LABORATORY"
40 PRINT " DO NOT INCLUDE THE UNITS"
50 PRINT
60 REM STUDENT INPUT OF DATA
70 PRINT "REACTION 1 (SODIUM HYDROXIDE SOLID + WATER)"
80 PRINT " MASS OF NAOH PELLETS"
90 INPUT M1
100 PRINT
110 PRINT " INITIAL TEMPERATURE OF WATER"
120 INPUT T1
130 PRINT
140 PRINT " FINAL TEMPERATURE OF WATER"
150 INPUT T2
160 PRINT
170 PRINT "REACTION 2 (SODIUM HYDROXIDE SOLID + HYDROCHLORIC ACID)"
180 PRINT " MASS OF NAOH PELLETS"
190 INPUT M2
200 PRINT
210 PRINT " INITIAL TEMPERATURE OF HCL"
220 INPUT T3
230 PRINT
240 PRINT " FINAL TEMPERATURE OF HCL"
250 INPUT T4
260 PRINT
270 PRINT "REACTION 3 (SODIUM HYDROXIDE SOLUTION + HYDROCHLORIC ACID)"
280 PRINT " INITIAL TEMPERATURE OF HCL"
290 INPUT T5
300 PRINT
310 PRINT " INITIAL TEMPERATURE OF NAOH"
320 INPUT T6
330 PRINT
340 PRINT " FINAL TEMPERATURE AFTER REACTION"
350 INPUT T7
360 PRINT
370 PRINT
380 PRINT "***********************************************************
390 PRINT " RESULTS OF PROCESSING THE DATA"
400 PRINT "***********************************************************
410 PRINT
420 PRINT "DELTA", "HT. ENGY", "MOLES OF", "ENERGY REL."
430 PRINT "REACTION", " T", " RELEASED", "NAOH USED", "/ MOLE NAOH"
440 PRINT "Celsius", " CALORIES", " KILOCALORIES"
450 PRINT "-- ------------------------------------------------------"
460 LET C1=T2-T1
470 LET C2=T4-T3
480 LET C3=T7-(T5+T6)/2
490 LET E1=C1*200
500 LET E2=C2*200
510 LET E3=C3*200
520 LET N1=M1/40
530 LET N2=M2/40
540 LET N3=5E-02
550 LET E4=E1/N1/1000
560 LET E5=E2/N2/1000
570 LET E6=E3/N3/1000
580 PRINT "1",C1,E1,N1,E4
590 PRINT "2",C2,E2,N2,E5
600 PRINT "3",C3,E3,N3,E6
610 PRINT
620 LET R1=-1*E4
630 LET R2=-1*E5
640 LET R3=-1*E6
650 PRINT "2. DELTA H1 =";R1;"KCAL/MOLE"
660 PRINT "H2 =";R2
670 PRINT "H3 =";R3
680 LET R4=R1+P3
690 PRINT "5. DELTA H2 =";R2;"KCAL/MOLE"
700 PRINT "DELTA H1 + DELTA H3 =";R4;"KCAL/MOLE"
710 LET P1=(R2-R4)*100/P2
720 IF P1<0 GOTO 740
730 GOTO 760
740 LET P2=(R4-R2)*100/P2
750 LET P1=P2
760 PRINT "6. PERCENT DIFFERENCE (ERROR) =";P1;"%"
770 IF P1<=5 GOTO 820
780 IF P1<=10 GOTO 840
790 IF P1>=50 GOTO 880
800 IF P1>=25 GOTO 860
810 GOTO 890
820 PRINT "NICE GOING!! LINUS PAULING, MOVE OVER!!"
830 GOTO 890
840 PRINT "OK. YOUR DATA VERIFIES THE CHEMICAL PRINCIPLE BEING STUDIED"
850 GOTO 890
860 PRINT "FAIRLY HIGH PERCENT ERROR. RECHECK YOUR DATA."
870 GOTO 890
880 PRINT "ASTRONOMICAL! YOU SHOULD RECHECK YOUR DATA!"
890 PRINT
900 PRINT "COPY THESE VALUES DOWN IN YOUR LAFOPATOPY NOTEBOOK SO THAT"
910 PRINT "YOU CAN CHECK YOUR ANSWERS TONIGHT. REMEMBER, YOU MUST"
920 PRINT "SHOW HOW YOU GOT THE ANSWERS TO RECEIVE CREDIT!!!"
930 END
10 PRINT "EXPERIMENT 27 - HEAT OF REACTION FOR THE COMBUSTION OF Mg"
20 PRINT
30 PRINT "TYPE IN YOUR OWN DATA FROM THE LABORATORY"
40 PRINT " DO NOT INCLUDE THE UNITS"
50 PRINT
60 REM STUDENT INPUT OF DATA
70 PRINT "REACTION 2 (MAGNESIUM OXIDE)"
80 PRINT " MASS OF MgO =";
90 INPUT M1
100 PRINT
110 PRINT " INITIAL TEMPERATURE OF HCL =";
120 INPUT T1
130 PRINT
140 PRINT " FINAL TEMPERATURE OF HCL =";
150 INPUT T2
160 PRINT
170 PRINT "REACTION 3 (MAGNESIUM METAL)"
180 PRINT " MASS OF Mg RIBBON =";
190 INPUT M2
200 PRINT
210 PRINT " INITIAL TEMPERATURE OF HCL =";
220 INPUT T3
230 PRINT
240 PRINT " FINAL TEMPERATURE OF HCL =";
250 INPUT T4
260 PRINT
270 PRINT
280 PRINT "*****************************************************************************"
290 PRINT " RESULTS OF PROCESSING THE DATA"
300 PRINT "*****************************************************************************"
310 PRINT
320 LET T5=T2-T1
330 LET T6=T4-T3
340 PRINT " 2. MgO DELTA T =";T5;"DEGREES CELCIUS"
350 PRINT " Mg DELTA T =";T6;"DEGREES CELCIUS"
360 LET E1=T5/10
370 LET E2=T6/10
380 PRINT " 3. ";E1;"KCAL (MGO REACTION)"
390 PRINT " ";E2;"KCAL (MG REACTION)"
400 LET N1=M1/40.3
410 LET N2=M2/24.3
420 LET H2=E1/N1
430 LET H3=E2/N2
440 PRINT " 4. ";H2;"KCAL/MOLE MGO"
450 PRINT " ";H3;"KCAL/MOLE MG"
460 LET H1=-1*(H3+68-H2)
470 PRINT " 5. DELTA H1 =";H1;"KCAL/MOLE Mg"
480 LET P1=(-142-H1)*100/(-142)
490 IF P1<0 GOTO 510
500 GOTO 530
510 LET P2 = (H1 + 142) * 100 / (-142)
520 LET P1 = P2
530 PRINT " PERCENT ERROR ="; P1; "%"
540 IF P1 <= 5 GOTO 590
550 IF P1 <= 10 GOTO 610
560 IF P1 >= 50 GOTO 660
570 IF P1 >= 25 GOTO 630
580 GOTO 680
590 PRINT "CONGRATULATIONS! YOU MUST BE A BRILLIANT CHEMIST!"
600 GOTO 680
610 PRINT "O.K. YOUR DATA AGREES WELL WITH THE ACCEPTED VALUE."
620 GOTO 680
630 PRINT "NOT TOO CLOSE TO THE ACCEPTED VALUE. ARE YOU SURE ALL OF"
640 PRINT "YOUR READINGS ARE CORRECT?"
650 GOTO 680
660 PRINT "DOWN THE TUBES!! OH WELL, YOU CAN ALWAYS BLAME IT ON"
670 PRINT "YOUR LAB PARTNER! RECHECK YOUR DATA."
680 PRINT
690 PRINT "COPY THESE VALUES DOWN IN YOUR LABORATORY NOTEBOOK SO THAT"
700 PRINT "YOU CAN CHECK YOUR ANSWERS TONIGHT. REMEMBER, YOU MUST"
710 PRINT "SHOW HOW YOU GOT THE ANSWERS TO RECEIVE CREDIT!!"
720 END
10 PRINT "EXPERIMENT 29 - CHEMICAL EQUILIBRIUM"
20 PRINT
30 PRINT "TYPE IN YOUR OWN DATA FROM THE LABORATORY"
40 PRINT " DO NOT INCLUDE THE UNITS"
50 PRINT
60 PRINT "THE DATA FOR THIS EXPERIMENT CONSISTS OF THE DEPTH (IN MM) OF"
70 PRINT "THE COLORED SOLUTION IN EACH VIAL AS COMPARED TO VIAL #1."
80 PRINT "VIAL #2;"
90 INPUT A2
100 PRINT "VIAL #1;"
110 INPUT E2
120 PRINT
130 PRINT "VIAL #3;"
140 INPUT A3
150 PRINT "VIAL #1;"
160 INPUT E3
170 PRINT
180 PRINT "VIAL #4;"
190 INPUT A4
200 PRINT "VIAL #1;"
210 INPUT E4
220 PRINT
230 PRINT "VIAL #5;"
240 INPUT A5
250 PRINT "VIAL #1;"
260 INPUT E5
270 PRINT
280 PRINT
290 PRINT "*******************************************************************************"
300 PRINT " PROCESSING THE DATA"
310 PRINT "*******************************************************************************"
320 PRINT
330 PRINT "VIAL 1", "VIAL 2", "VIAL 3", "VIAL 4", "VIAL 5"
340 PRINT
350 PRINT "A. INITIAL Fe CONCENTRATION (AFTER MIXING, BEFORE REACTION)"
360 PRINT "1.0E-1", "4.6E-2", "1.6E-2", "6.4E-3", "2.6E-3"
370 PRINT "B. INITIAL SCN CONCENTRATION (AFTER MIXING, BEFORE REACTION)"
380 PRINT " IN ALL TUBES 1.0E-3"
390 LET R2=B2/A2
400 LET R3=E3/A3
410 LET R4=B4/A4
420 LET R5=E5/A5
430 PRINT "C. VIAL HEIGHT RATIOS"
440 PRINT "------", R2, R3, R4, R5
450 LET D2=R2*1E-03
460 LET D3=R3*1E-03
470 LET D4=R4*1E-03
480 LET D5=R5*1E-03
490 PRINT "D. EQUILIBRIUM CONCENTRATIONS OF FeSCN"
500 PRINT "1.0E-3", D2, D3, D4, D5
LET E2=4E-02-D2
LET E3=1.6E-02-D3
LET E4=6.4E-03-D4
LET E5=2.6E-03-D5

PRINT "E. EQUILIBRIUM CONCENTRATIONS OF FE"
PRINT "9.9E-2",E2,,E3,,E4,,E5

LET F2= 1E-03-D2
LET F3= 1E-03-D3
LET F4= 1E-03-D4
LET F5= 1E-03-D5

PRINT "F. EQUILIBRIUM CONCENTRATIONS OF SCN"
PRINT "0.0",F2,,F3,,F4,,F5

LET X2=D2/(CE2+F2)
LET X3=D3/(E3+F3)
LET X4=D4/(E4+F4)
LET X5=D5/(E5+F5)

LET Y2=E2*D2/F2
LET Y3=E3*D3/F3
LET Y4=E4*D4/F4
LET Y5=E5*D5/F5

PRINT "I WILL PAUSE NOW SO THAT YOU WILL HAVE TIME TO COPY WHAT"
PRINT "I HAVE CALCULATED SO FAR.
TYPE I WHEN YOU ARE READY TO CONTINUE."
INPUT X
PRINT

IF X<>1 GOTO 780
PRINT "RESULTS OF EQUILIBRIUM RATIO TRIALS"
PRINT "   A    B    C"
PRINT "2",X2,Y2,Z2
PRINT "3",X3,Y3,Z4
PRINT "4",X4,Y4,Z4
PRINT "5",X5,Y5,Z5

LET A=X2
LET B=X3
LET C=X4
LET D=X5
GOSUB 1160

LET A=Y2
LET B=Y3
LET C=Y4
LET D=Y5
GOSUB 1160
LET A=Z2
LET B=Z3
LET C=Z4
LET D=Z5
GOSUB 1160
1010 LET B=Z3
1020 LET C=Z4
1030 LET D=Z5
1040 GOSUB 1160
1050 LET Q3=Q
1060 PRINT "VALUE OF DEVIATION RATIOS"
1070 PRINT "",Q1,Q2,Q3
1080 PRINT
1090 PRINT "OMIT QUESTION NUMBER 8.";
1100 PRINT "ANSWER QUESTION NUMBER 9 ON THE FIRST PAGE."
1110 PRINT
1120 PRINT "COPY THESE VALUES DOWN IN YOUR LABORATORY NOTEBOOK SO THAT"
1130 PRINT "YOU CAN CHECK YOUR ANSWERS TONIGHT. REMEMBER, YOU MUST"
1140 PRINT "SHOW HOW YOU GOT THE ANSWERS TO RECEIVE CREDIT!!!"
1150 GOTO 1380
1160 IF A>=B GOTO 12100
1170 LET H=B
1180 LET N=A
1190 GOTO 1220
1200 LET M=A
1210 LET N=B
1220 IF C>=D GOTO 1260
1230 LET O=D
1240 LET P=C
1250 GOTO 1280
1260 LET O=C
1270 LET P=D
1280 IF M>=O GOTO 1310
1290 LET L=O
1300 GOTO 1320
1310 LET L=M
1320 IF N<=P GOTO 1350
1330 LET S=P
1340 GOTO 1360
1350 LET S=N
1360 LET Q=L/S
1370 RETURN
1380 END
CHAPTER 5

RESULTS OF THE PROJECT

Findings

A questionnaire was designed and administered to 27 chemistry students of the 1973-1974 school year to determine their attitudes toward the computer and this project. Because the project was not initiated until the second half of the chemistry course, these students used only the last four of the twelve programs of the project. The questionnaire, referred to as Form A (see Appendix C), consisted of four questions. These questions and the student responses to each, taken verbatim from the students' papers, are given below.
COMPUTER EVALUATION

The following questionnaire is anonymous. Please answer each question as completely and accurately as possible.

1. Did you spend more or less time preparing the report for the lab?

Less time spent
Less time
I spent less time
Much less time
Less

I spent less time writing the lab, because once I got correct answers I knew it and didn't have to recheck.

Spent less time writing on the lab
I spent less time on the lab write up (Also less worry after I got the correct calculations!)
Less time because I didn't need to do math
A little less

Yes, using the computer saved time when writing the lab

I spent more time trying to figure out the lab
I spent less time because I was more sure of myself as far as writing the equations I knew when I had it right or wrong, and I knew what to look for
The computer saved me about 5 extra minutes
It saved me considerable time
Less
I spent less time
Saved a small amount of time, because when you
know the answer, it's easier to figure out how
to do it
Saved time
In a way it took more time because I never got
the same answer as the computer did. If I
knew how to do the problems right, it
probably would help
Less time
I feel I used about the same amount, maybe
slightly more. I was still slightly confused
after I did the work. Had to go back over
problems and work them until I got the right
answers
Saved time
I spent less time because I already knew if I
did it right
I think it saved time until I kept getting the
wrong answer and had to do it over and over
Saved time, because I could work toward the known
answer
It saves time because if I get on the wrong track in finding an answer I can find my mistake, and then learn how to work the problem properly.

Used more time because I wanted to see if it was right.

2. Did you feel writing the report was easier or harder with the computer?

Easier

It was just as difficult because I check the answers.

It was easier. But it would've been harder if I didn't know how to do the calculations.

It was much easier.

Easier

I found that it was easier to write the lab because I could be sure when I got the right answers and I could see where I was going.

Writing the lab was easier because we knew what we were supposed to end up with.

It was harder because your competing against a machine, always right and exact. It was easier when you could get the wrong answer.

Writing the lab is the same.

Yes

Writing the lab was easier after using the computer.
Easier
Yes, definitely. Again, I was able to understand what equations were needed, and I knew when I was right.
The lab was about the same as it always was.
Easier
An easier task because on two questions without the computer I would have really messed up.
Harder. I had to figure out the answers so they came out the same.
Slightly easier
Computer made the job at home easier, because I didn't have to double-check all of my answers.
The computer made me work more to get the right answers on the questions.
Because you were able to check your work by having the answers, it was easier. If you don't have the answers you have to worry about getting the wrong answer and not knowing how to do it when we went over lab in class.
It helped me a little more because I was able to find the right way to solve the problems. However, it seemed that I was hurting myself by using the answer and working out the problem backwards. It didn't seem that I was learning as much as I would if I made mistakes.
Easier because I had the answer to see if I was doing it right. When I didn't get the answer I could do it over while I was still on the same question.

It made it a lot easier

It helped because I knew where I was heading and what I needed to obtain

Easier at home

It made it easier at home

3. Do you feel you had a better understanding of the chemical principles of the lab?

Yes, the computer helped some

Yes

I understood it better only because I could do the calculations

Sort of

Sort of. I still didn't understand the whole thing

Had about the same understanding

Yes, I really understand, now, why I got the answers I did and how it's done for the first time - I was never absolutely certain before

Yes

I feel that the computer didn't change what we learned because we still had to write up how we got the answers
Had about the same understanding
Sort of. I still didn't understand the whole thing
Sort of
I understand it better only because I could do the calculations
Yes
Yes, the computer helped some
No
My understanding of the lab was neither decreased or increased
Didn't help or hurt
It made it fun, but about helping me understand the lab I really don't know
In this case, maybe increase because the importance of getting correct data was more apparent
No, I still had to ask my brother for help
No
Increased
I think that it was probably about the same
The lab concepts weren't affected by the use of the computer
Slightly'
Yes, definitely. I saw the computer answers, and then figured it out on my own
4. What did you like about using the computer?
What did you dislike? Was the lab more
enjoyable?
I think it made it alot more fun and much more enjoyable
It made the lab more interesting for most people
I liked using the computer because it showed us the percent error and we could do it over to get it right. It makes you think about your experiment methods
No
Computer helped alot
It made the lab more enjoyable and we weren't just doing a lab and then doing the questions by ourselves
The computer helped, because it let you know if you did the lab right or not
The computer made for an interesting change
Yes, it was more enjoyable to see the way the computer ran and figured the answers out
OK
It was no big deal
It was fun. You knew right away if you had done something wrong before you got the lab back a few days later through percent error. Then later stupid mathematical mistakes and wrong ways were ruled out because you knew what the answer was
I think that it was an experience using the computer. I enjoyed it. It made the lab go faster.

I liked using the computer because it cut down my working time, and made it over-all easier and more relaxing (I didn't have to worry about whether I was doing it right or not).

The use of the computer proved the means for having a fast guide, easy checks, on my answers. It proved to be useful.

It was more fun doing the calculation on the computer.

The computer was a time saver and it helped me to figure out what I was supposed to be figuring out.

I enjoy work that I'm successful at.

It was more fun and more interesting to do. I enjoyed plugging the numbers into the computer in a search for valuable information. It would have been less fun if the #'s meant nothing, but the information the computer gave us really meant something, and what I did in the lab was really important. I enjoyed it.

It gave me an idea of what kind of answers I should've gotten.
The responses to this questionnaire were tabulated into three groups (favorable, neutral and unfavorable) in order to summarize the comments. The results are as follows:

<table>
<thead>
<tr>
<th>Question</th>
<th>Favorable</th>
<th>Neutral</th>
<th>Unfavorable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>17</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

NOTE: Seven students failed to respond to Question 4.

To evaluate the remaining programs of the project, which were used by 46 chemistry students of the 1974-75 school year, a new questionnaire was developed. In order to obtain objective as well as subjective data, questions were devised so that the students were able to indicate their attitudes on a sliding scale of one to five. All of the questions were phrased so that positive attitudes toward the project would be expressed as high numbers. All student responses were tabulated. The percentage of students indicating each number was calculated as well as the average student response. Space was then allowed so that the students could give comments explaining the numerical response they had given if they so wished. These
comments were taken verbatim from the students' papers. This questionnaire is referred to as Form B (see Appendix D). The results of that evaluation are as follows:

STUDENT EVALUATION OF COMPUTER APPLICATION IN CHEMISTRY

This is an anonymous questionnaire designed to evaluate the effectiveness of the computer as it has been used in chemistry class this year. Please respond to each question based on your own feelings and attitudes. Circle a number, one to five, to indicate your answer to each question. Use the comment sections to explain your responses to the number lines.

1. Did using the computer help to give you a better understanding or did it interfere with understanding the chemical principles of the lab?

<table>
<thead>
<tr>
<th>Interfere</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Better Understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>1</td>
<td>1</td>
<td>9</td>
<td>19</td>
<td>17</td>
<td>Average Student Response 4.06</td>
</tr>
<tr>
<td>%</td>
<td>2</td>
<td>2</td>
<td>19</td>
<td>40</td>
<td>36</td>
<td></td>
</tr>
</tbody>
</table>

Comments:

Gave better understanding and provided methods of study

It did not really help my understanding, but it
let me know when I goofed.

I like it

It helped me in almost all the areas but sometimes it got me confused on some of the questions

Helped

I thought it was pretty good because it helped to clarify some of the questions I had on how to figure out some of the problems

It helps somewhat

I don't think it really interfered with my understanding

It helped me to know if I was doing something wrong

It helped to realize my errors and why they were made

The computer doesn't really effect my knowledge of chemical principles

The computer didn't really give me a better understanding because it just gave the answers and not the procedure

It saved time, as well as showed you how much error there can be in a chemical experiment

It made it easier for me because I had the answers from the computer to compare my answers with, so if they were wrong I could find the answer and the correct process

At times it was easier but at times it would have
been easier to have the teacher's help
I don't really feel that it affected me either way, as far as understanding chemical principles goes.
The computer gives all the problems and answers, the figuring out is the fun part
You could use the computer's calculations to check any work you did
It helps, if the people understand some of what's going on. People who don't already have an idea of the workings of the chemical problems become dependent, those who understand are helped greatly though.

2. Do you feel that writing the report was easier or harder with the computer?

<table>
<thead>
<tr>
<th>Harder</th>
<th>0</th>
<th>0</th>
<th>4</th>
<th>10</th>
<th>32</th>
<th>Easier</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Average</td>
</tr>
<tr>
<td>%</td>
<td></td>
<td></td>
<td>9</td>
<td>22</td>
<td>70</td>
<td>Student</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Response</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.61</td>
</tr>
</tbody>
</table>

Comments:
Really helped in writing and understanding
It made no difference
It saved a lot of time
Easier to visualize what was supposed to happen
I think that the computer helped by giving the right answer. Then, if we made a mistake, we could tell by looking at the computer
Helped

It was easier but I didn't understand what was going on

When stuck I could use the computer answer to discover what to do

You had a better understanding with the proper figures

It helps to check one's answers

Easier because you would know whether you were working the problems right or not

It helped me, more because I could check my answers with the computer's to see if I'm doing the work correctly

It helps me get my information organized

It gave me something to start with

I could see where I made math mistakes before turning in my report

Easier because I could check my answer to see if I got it right

It was a lot easier because the computer does all the figuring for you

One doesn't have to do the figuring

Because I could check my answers with the computer's and make sure I was doing it right.

I was able to check my answers and correct my errors that I had made
Easier because I would know the answers and work toward them

3. Did you spend more or less time preparing the report for the lab?

<table>
<thead>
<tr>
<th>More</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Less</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>2</td>
<td>2</td>
<td>18</td>
<td>17</td>
<td>8</td>
<td>Average Student Response 3.57</td>
</tr>
<tr>
<td>%</td>
<td>4</td>
<td>4</td>
<td>38</td>
<td>36</td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>

Comments:

Tried doing lab report first without computer
I spent the same amount either way
I don't really have anything to compare with
This was, because I took longer to show my work and get a better grade
Took the same amount because you had to do it yourself anyway
I tried to do the complete report without any assistance if possible
I worked the problems myself to see how they were done, and then compared that answer to the computer readout
Perhaps if we did our work first and then checked our answers with the computer
I spent less time preparing the report because I could check with the computer
I don't know
Helps you to find your error
It gave me a starting point
I made lots of goofs, and could see them, so I corrected them
I spent the same amount of time
Less time using the computer to prepare the lab, because it took less time to check my answers
The same
Sort of. I did some of the problems to see if I could get the same answer
Does not affect time
The same really, maybe a little more different if I went through all the steps and the answers didn't match, I did it all over again
Same
4. Was the laboratory experience more or less enjoyable with the computer?

<table>
<thead>
<tr>
<th>Less</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>More</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>15</td>
<td>27</td>
<td>Average Student Response 4.43</td>
</tr>
<tr>
<td>%</td>
<td>0</td>
<td>2</td>
<td>9</td>
<td>32</td>
<td>57</td>
<td></td>
</tr>
</tbody>
</table>

Comments:
It let me know when I made a mistake quickly so I could correct it
Some of the answers and % errors were pretty funny
I like computers and the way they were used in the
experiment
I really enjoy knowing our % error
You could do the lab and run your program through
the computer without worrying if you dropped a
decimal or made another error in your calcula-
tion
It is very enjoyable to work with the computer
It's more interesting
The experience was more enjoyable, I think
Less, it took a lot of time to get in on the
computer
I liked the cute comments
I like playing with the computer
I enjoyed it more with the computer because I had
never used a computer before
It was more enjoyable because I could understand
the methods for calculating the answers better,
except when we find 60% error
It makes it more fun because it's different than
other classes
Everybody was trying to see everyone else's
errors and then trying to correct them
Doesn't really make a difference
I enjoy working with the computer in general
I like to use the terminal and make attempts for
"perfecting"
5. Was the computer a useful check on your lab technique?

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>40</td>
<td>Average</td>
</tr>
<tr>
<td>%</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>9</td>
<td>85</td>
<td>Student Response 4.77</td>
</tr>
</tbody>
</table>

Comments:

It helped find mistakes
I don't think so because I know many people who made mistakes and got low percent error
I was relatively sure I was correct without it
Yes, it was
Yes a couple of times we made serious mistakes, but we could see where we went wrong with the experiment
Yes because if I got a different answer than the computer then my technique was wrong
Very much so. By using the computer I saw how sloppy my techniques were
It was an excellent check
None
It just was
It gives comments and tells % error also
6. Do you ever repeat a portion or all of a lab due to a high percent error?

<table>
<thead>
<tr>
<th>Never Repeat</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Often Repeat</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>11</td>
<td>12</td>
<td>11</td>
<td>11</td>
<td>2</td>
<td>Average Student Response 2.36</td>
</tr>
<tr>
<td>%</td>
<td>23</td>
<td>26</td>
<td>23</td>
<td>23</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

Comments:

Sometimes. When something wrong in the lab we checked
Once I did
Not very often high error. But when we do, we try and find the goof.
Sometimes we have a high percent error because of bad lab technique
I did once
I did once
Did not really have high percent errors
Only once
Yes we did. But what we considered high percent error is 6% or more
Once I re-weighed a beaker and found that I misread the balance
We never had an unacceptable error
Twice
Not too often. We usually get low % error
I re-weighed a vial once, and found that I had
made a mistake the first time I weighed it

7. Was having the computer answers to the problems a help or a hindrance?

<table>
<thead>
<tr>
<th>Hindrance</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Help</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>9</td>
<td>34</td>
<td>Average Student Response 4.64</td>
</tr>
<tr>
<td>%</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>19</td>
<td>72</td>
<td></td>
</tr>
</tbody>
</table>

Comments:

It helped somewhat
They were there but you had to figure them out
Because if I came out with a wrong answer, I was able to go back and find my mistakes
It helped to check the answers. But it would be nice if we knew the molar mass the computer is programmed to
A help because you knew whether or not you were getting the problem right
It was a help because I could check
It helps me to see if I am doing them right
Greatly easier
It helped a lot
I have the numbers to work with so I know if I am right

8. Did you feel threatened by or resent the computer?

<table>
<thead>
<tr>
<th>Yes</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
No. 1 0 4 0 42 Average Student Response 4.74
%
2 0 9 0 89

Comments:

How can you resent something that is fun and a great help?
Why should I, it helps me
If anything the computer helps
It was a responsibility not to use it wrong
There is nothing to be threatened about
It's a tool not an adversary
It's only a machine
Ha!
I don't feel threatened or resented
Not at all
I don't see how I could feel threatened by the computer. The computer is about as dangerous as a television or a radio. The only thing it could do is blow or electrocute me.

9. Do you feel as though you were competing against other students in the class because of the percent error computation?

Competing 1 2 3 4 5 Not Competing
No. 5 9 14 10 9 Average Student Response 3.19
%
11 19 30 22 19
Comments:

I think that if we got a bad percent error the rest of the class looked on us as though we had made some incredible error. I just try to do my best. I'm interested in what other people get but I'm worried the most about myself. I'm just out to get the best grade I can.

Mostly only against myself.

Everyone tried to be perfect.

Some people feel that way.

I feel other people are competing to get the best % error. I don't care what others get.

Well I do sort of, I mean I would like it if everytime I got 0% error.

Sort of.

A little but it's fun.

No because I was using a completely different balance scale.

I felt a few were competing against me.

Yes, because it effects your laboratory grade and that effects your overall grade.

Sometimes, sometimes not.

Makes me want to do better.

Sort of, but not really serious competition.

It gives a thrill just like competing in a race.
10. If you could make the decision, would you favor eliminating the computer completely from class or favor developing more programs so that it could be used more?

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Use More</th>
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</thead>
<tbody>
<tr>
<td>No.</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>11</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>0</td>
<td>2</td>
<td>6</td>
<td>23</td>
<td>70</td>
<td></td>
</tr>
</tbody>
</table>

Average Student Response 4.57

Comments:

- It helps speed things up, so it should be used more
- Keep it, it's an accurate quick check on lab technique
- I don't really think that it should be developed more in the class. I think that the students might be doing too little work
- I feel it should be developed more and would like to see it in math, for instance
- I like punching the buttons
- It should be used just about as much as we've been using it
- Because the computer helps me I would like to keep using it
- If we changed anything I'd like to use it a little more
- It helps so much!!!
More comments could be made in the programs
Definitely
Please develop more programs
It would be neat to be able to use it more
I want to go also into computer programming
11. What did you like most about the computer?
Use of it and the help with labs
Being able to feed in the data myself and watch-
ing the computer process it
I liked being able to check answers and getting
% error so I know how well I'm doing in the
lab
It's quickness and accuracy and also it's crazy
comments afterwards
It breaks up the monotony found in other classes,
gives the teacher more time in answering
questions, and is very accurate and quick
Checked lab
Having the answers to the calculations to work
while doing the lab report
The experience
The answers of most of the questions which makes
it better to understand the methods for cal-
culation
I saw where I went wrong
Using it. I thought it was fun
I can practice for computer programming
The computer really helped me to understand how to work out the problems. It gave me something to check my answers with. The help on the lab reports could check your work against it, and if you goof you could work backwards from the answers. You had the answer which made it easier to calculate the problem. That I can check my mistakes and find out what part of the lab I don't understand. With the answers given to you, you can check your problems for a better understanding. It makes sure you have the correct answers. It helped you figure out how the answers were found out and if you are figuring it out right. You could get the answers to your lab in a matter of seconds, and you would know whether your own answers were correct. You have the answers already and all you have to do is work the problem out. I learn a lot more this way. It gives us the answers to the questions in the lab so that we can learn better and easier. I liked how efficient it was. It helps me to understand how to get the answers when processing the data. Having it give the correct answers to the lab
I was grateful for a check on my lab and knowing percent error was not only useful but made the labs much more enjoyable. Being able to have an answer key to look back on when I was doing my lab to see if I was doing it right, I could find out the percent error in the experiment. Having the right answers helped because I could work the problems out and if I had a wrong answer I could check where I made the mistake.

You get your answers easier. It is just a good aid in helping us understand the labs. Liked almost everything. It gave us an answer which we could check with and correct our mistake. The speed. If a high degree of error came up, figures could be checked and program rerun. It gives you your percent error. It helped me to understand the labs, and the percent error told me how the experiment came out. The percent error readouts and the answer computations.

If I couldn't figure out some answers, I could work backwards to find out how to work them.
It saves time and it provides correct answers so that when you work the problems at home you can catch your mistakes and learn how to do the problems correctly.

It helped me find errors I had made.

It provided a means of checking work completed. I tried to do labs without computer results, then checked my work. It really helped.

12. What did you like least about the computer?

- Limited use due to class size
- Programming errors
- The long lines to use it, and sometimes it would be programmed to give wrong answers
- Nothing; it's a great help. Keep it going
- Waiting in line
- Typing up all the data except last line and then making a mistake
- I don't understand how you get the answers
- The long waiting line to get to use it
- Standing in long lines all through nutrition
- Not understanding how it derived the answers
- The lines were too long
- When it made a mistake on one of my labs
- There are too many people trying to use the same one at the same time
- It calculates the answers faster than I do
- A lot of people were in line for it, but that
wasn't too bad at all. I also didn't like the high percent errors it gave me. I really can't think of anything. As long as I use the computer sheet as an answer sheet, it's alright.
Summary and Conclusions

A high numerical response was given to questions 2 and 3 of Form A, and to 1 and 2 of Form B. This would indicate that based on the students' own assessments, the laboratory exercises were easier to understand. Most students also gave positive responses to question 7, indicating that having the correct answers to the problems they were solving was of value.

A few students indicated by their comments that the computer should have solved all their problems for them in total, thus eliminating the need to think. It was not intended that the computer be a panacea or that with it all chemistry students would excel in the subject. It was intended that the project be a computational aid to increase the students' understanding of the concepts being studied. It would be foolish to think that any educational method would result in 100% understanding on the part of all students.

With the exception of only a few students, an overwhelming majority felt the computer was a useful check on their lab technique, as indicated by an average rating of 4.77 on question 5 of Form B. One fault with the error computation is that a student could have made mistakes and still have received a low percent error. This was possible if the student had made several mistakes which
happened to cancel out each other. Most students, however, felt the computer was a useful check on their lab technique.

Question number 6 of Form B was the only item that was ranked below a neutral value of 3. This question dealt with repeating laboratory work due to a high percent error as given by the computer. Many of the comments indicated that a number of students did not need to repeat the lab because they had an acceptable percent error (under 10%) the first time. This is encouraging, in that most students seem to have good laboratory skills and can properly follow directions. It is possible that the computer did serve a purpose here, in that the students were more careful about the measurements they made, knowing their values would be checked by the computer.

As indicated by question 4 of both Form A and B, most of the students enjoyed the laboratory experience more with the computer project. They liked having their work checked with no penalty. If their data contained errors, they could correct the errors before submitting their reports for a grade. The only negative feelings expressed on this item dealt with the time lost waiting in line to use the computer facilities. This is more a function of the equipment available rather than the project itself. The comments given indicate that, if no wait was involved, the project would meet with virtually all the students' approval.
It was difficult to interpret the results of question 9, dealing with the competition factor. When the question was written, it was felt that competition for a low percent error would have negative effects in that some students would feel pressured and resent the computer. Some students did feel as if they were in competition, but not with the other students. Many comments indicate that the students felt the competition was with themselves. These and the others generally felt that, if a competition factor was involved at all, it was enjoyable and led to a more diligent effort.

Many educators feel that the general public has a resentment and fear of computers. This did not seem to be the case with students involved in this project. Most comments regarding this factor (question 8) indicated a "Why should I be threatened?" attitude. It is possible that young people growing up in the age of computers do not have the same anxieties about computerization that their parents have.

This project did not seem to save most students a great deal of time in preparing their laboratory reports, or make writing those reports significantly easier. Knowing they would be graded on the method they used to solve the problem rather than on the correct answer itself, most students spent approximately the same amount of time on their reports as they would have without the project. Students did find, generally, that having the answers to
the problems was an aid. They knew when they had solved a problem correctly that they could proceed to the next problem in the sequence with confidence. If they had made a mistake, they could correct their work before compounding the error.

Question 10 indicates that the project met with overwhelming success. Individualization was possible that could not have been reasonably accomplished by any other media. For the first time, a student's data could be checked before the student left the lab in a minimum amount of time. Students who found a relatively high error in their data even spent nutrition or lunch to repeat the experiment in order to reduce their error.

Recommendations

One of the major factors contributing to the success of this project was the immediacy of feedback to the students. The terminal used was located in the chemistry room where the students were conducting the laboratory exercise. As soon as they finished collecting their data, they walked only a few feet to verify their findings. If they had made errors, the students could re-examine their findings, make additional observations and then re-enter their data immediately. Also, the instructor could be in the classroom and also at the terminal to give
help and offer explanations. If the terminal had been located in some distant spot on campus, the immediacy factor would have been lessened. It is recommended that the computer facilities be located as closely as possible to the site of the student work.

Different types of terminals each have their own advantages. A CRT terminal was used for this project. Its advantage was speed in that it printed 30 characters per second. However, a CRT terminal does not provide the student with a copy of what is printed. The students had to copy from the television screen information calculated by the computer. This problem was partially solved by the introduction of the student work sheets. All material given by the computer that was the same for each run (titles, instructions, etc.), was given to the students on a printed sheet. This minimized the amount of material each student had to copy from the screen. The length of time the students had to wait in line was reduced, but this still remained the major student complaint about the project.

It is recommended that a project such as this one be implemented with a teletype terminal. This unit prints characters at less than half the rate of a CRT (11 per second), but the final result would be less time required per student. The slower printing rate is more than compensated for in the printing of a hard-copy of the student's results. The student would simply have to tear off the
printed message and make the unit available for the next student.

One of the most popular aspects of the project was the comment the student received on the accuracy of his percent error. Not knowing how the computer was programmed, the comments come as a complete surprise. Light-hearted statements such as "Wooowwwwww!!!! A superchemist!" were not expected from a machine! It would be possible to modify the programs to be even more student-sensitive. The program could check each piece of data entered against accepted reasonable measurements. At the end of the run, the student could then be specifically directed to possible sources of error as, "re-check the initial mass of the beaker." This would also help eliminate the problem of students receiving a low percent error because of compensating mistakes.

Little instruction was given to the students who were the subjects of this project. The instructor remained near the terminal, and helped each student solve problems concerned with the use of the terminal as the need arose. It is recommended, however, that a thorough introductory lesson be given to any student who is using the terminal for the first time. Items such as how to initiate a run of the program and how to correct typing errors could be introduced. This would solve many individual problems before they arose.
Evaluation of this project was mainly in the affective domain. Students' assessments of their own attitudes were tabulated. In order to be proved cognitively valid, the project should be evaluated in terms of changes in the level of understanding on the part of the students. The problem lies in the difficulty of analyzing how much increased learning has taken place. We do not know how to accurately determine when someone has learned. Evaluation of this nature is a project in itself. It is recommended that this type of study be made.

At this time, there is a severe shortage of computer programs that can be used directly by students in the classroom. This situation prohibits the more widespread use of computers by students as an aid to learning. As more projects such as this are developed and as programs are shared between those interested in applying computers to education, a more extensive application of this valuable resource will be possible.
REFERENCES


APPENDICIES
APPENDIX A

Sample Laboratory Experiment
Weighing an Object Immersed in Two Different Fluids

In this experiment you will investigate the relationship between the mass of an object, its volume, and the environment in which the weighing is done. The mass will then be related to the volume of the object.

Two different objects will be weighed separately, first when immersed in air, and second when immersed in water.

PROCEDURE

a. Record the number of your objects to distinguish them from those of your classmates.
b. Weigh each of your two objects in air to the nearest 0.1 gram.
c. Weigh each of your two objects to the nearest 0.1 g when they are completely immersed in water. Be sure there is no direct contact between the object being weighed and the vessel containing the water. See Figure 4-1.
d. Make the measurements needed to determine the volume of each object to the nearest 0.1 ml. Use the water displacement method.

PROCESSING THE DATA

1) For each object, determine the difference between the apparent mass in air and the apparent mass in water. The reason for using the phrase "apparent mass" rather than "mass" will be clear when this experiment is completed and discussed in class.
2) Determine the volume of each object.
3) Does the mass of an object or its volume have a greater effect on the difference between the apparent mass of an object in air and its apparent mass in water? Explain.
4) Determine the mass of water displaced by each object. One gram of water occupies 1.0 milliliter.
EXPERIMENT 4

5) Determine for each object, the value of the ratio
   \[
   \frac{\text{mass of water displaced}}{(\text{apparent mass in air}) - (\text{apparent mass in water})}
   \]

6) Express in words the significance of the value found for the ratio in item 5 above.

7) Will an object have a greater apparent mass in a vacuum or in air? Why?

8) One liter of air at room temperature and normal atmospheric pressure has a mass of 1.18 g. What would have been the mass of your objects had they been weighed in a vacuum?

9) Why is the adjustment suggested in item 8 above not usually made on weighings made in air?

---

Figure 4-1
Weighing an object immersed in water.
APPENDIX B

Sample Student Data Sheet
Sample Student Data Sheet

Name________________
Period________________
Date________________

EXPERIMENT 4 - WEIGHING AN OBJECT IMMERSED IN TWO DIFFERENT FLUIDS

Fill in the following data table with the values you collected in the lab before sitting down at the terminal.

CYLINDER NUMBER 1

MASS IN AIR? _________
MASS IN WATER? _________
VOLUME OF WATER IN GRADUATE? _________
VOLUME OF WATER + CYLINDER? _________

CYLINDER NUMBER 2

MASS IN AIR? _________
MASS IN WATER? _________
VOLUME OF WATER IN GRADUATE? _________
VOLUME OF WATER + CYLINDER? _________

************************************************************************************************************

PROCESSING THE DATA
************************************************************************************************************

1. MASS DIFFERENCE= _______ _______
2. VOLUME= _______ _______
4. MASS OF WATER DISPLACED= _______ _______
5. VALUE OF RATIO= _______ _______
<table>
<thead>
<tr>
<th>CYL #1</th>
<th>CYL #2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8. MASS IN A VACUUM=

PERCENT ERROR=

Remember, you must show how you got the answers to receive credit!!!
APPENDIX C

Questionnaire - Form A
Questionnaire - Form A

COMPUTER EVALUATION

The following questionnaire is anonymous. Please answer each question as completely and as accurately as possible.

1. Did you spend more or less time preparing the report for the lab?
2. Did you feel writing the report was easier or harder with the computer?
3. Do you feel you had a better understanding of the chemical principles of the lab?
4. What did you like about using the computer? What did you dislike? Was the lab more enjoyable?
APPENDIX D

Student Questionnaire - Form B
Questionnaire - Form B

STUDENT EVALUATION OF COMPUTER APPLICATION IN CHEMISTRY

This is an anonymous questionnaire designed to evaluate the effectiveness of the computer as it has been used in chemistry class this year. Please respond to each question based on your own feelings and attitudes. Circle a number, one to five, to indicate your answer to each question. Use the comment sections to explain your responses to the number lines.

1. Did using the computer help to give you a better understanding or did it interfere with understanding the chemical principles of the lab?

Interfere 1 2 3 4 5 Better Understanding

Comments:

2. Do you feel that writing the report was easier or harder with the computer?

Harder 1 2 3 4 5 Easier

Comments:
3. Did you spend more or less time preparing the report for the lab?
More 1 2 3 4 5 Less
Comments:

4. Was the laboratory experience more or less enjoyable with the computer?
Less 1 2 3 4 5 More
Comments:

5. Was the computer a useful check on your lab technique?
No 1 2 3 4 5 Yes
Comments:

6. Do you ever repeat a portion or all of a lab due to a high percent error?
Never Repeat 1 2 3 4 5 Often Repeat
Comments:

7. Was having the computer answers to the problems a help or a hindrance?
Hindrance 1 2 3 4 5 Help
Comments:
8. Did you feel threatened by or resent the computer?  
Yes 1 2 3 4 5 No

Comments:

9. Do you feel as though you were competing against other students in the class because of the percent error computation?  
Competing 1 2 3 4 5 Not Competing

Comments:

10. If you could make the decision, would you favor eliminating the computer completely from class or favor developing more programs so that it could be used more?  
Eliminate 1 2 3 4 5 Use More

Comments:

11. What did you like most about the computer?

12. What did you like least about the computer?