ABSTRACT

EVALUATION OF MULTIMEDIA CHEMISTRY COURSEWARE

by
Ryan D. Isahac

With the every growing costs of running a Chemistry laboratory and the ever-changing needs

of today's students a logical alternative seems to be a computer based instructional format.

When delivering courseware via the Internet, the greatest problem comes in making the

interface and applications user-friendly and not just attractive. In order to test the utility of

such a site, subjects are recruited and asked to evaluate the system. Their responses are

essential in designing and improving the program to best meet the needs of students.

In order to address student concerns, a Help Page was developed which clarified areas and

sequences of steps that students found confusing. A major component of the multimedia

system developed in this project is the Pre-Lab Quiz which consists of both numerical and

multiple choice questions. Concepts involved in solving multistep problems are structured so

that an intelligent tutoring system could also be implemented. A randomization scheme for

the input data in the numerical questions is developed and this insures that the prelab quiz is

unique for each student.

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by
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To my family

ACKNOWLEDGEMENT

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CHAPTER 1

INTRODUCTION

1.1   Objective

There is no place for the specialist in our world of work. He has been replaced by multi-disciplinarians. With the advent of the Internet, information has become easily accessible, but increasingly difficult to manage. The ability to sort through the wealth of information has become a necessary skill. However, one does not automatically accept information at face value when accessed through the Internet, you must examine it thoroughly, examine its source and determine whether it is reliable (or whether the information provided is unfounded). This process of examining information before accepting and integrating into one's knowledge base is the basis of the constructivist theory. The more exciting prospect emerges when the constructivist mode of education interacts with multimedia presentation of science.

1.2   Purpose

The greatest difficulty in transmitting science to students is relating its real-life significance and importance. Multimedia tools allow us to introduce interdisciplinary genres into the science education paradigm through the use of technological tools that are lacking in traditional science classrooms. Several adversities accompany the incorporation of these technological elements and the goal of this project was to address the educational challenge posed by the application of chemistry education via multimedia.

The work described in this thesis was part of a project to develop and improve web based multimedia courseware for use by NJIT and Rutgers-Newark General Chemistry students. The sections addressed concern the Help Page and the creation of Numerical and Multiple Choice Questions for the Pre-Lab Quiz and Pre-Lab Exercise. The thesis also addresses student evaluation of the software in question and their role in the improvement of the site.

CHAPTER 2

LITERATURE REVIEW

2.1   Background

2.1.1   CAI and Chemistry Education

In terms of using CAI for delivering Chemistry (Lab) techniques and theories, the benefits far outweigh the detriments. Perhaps the most dominant problem involved in running a Chemistry Lab is cost. There are costs involved in initial capital investments, laboratory supplies and safety equipment, laboratory proctors (TA's) and their requisite training, and other such factors. As with a traditional laboratory, initial costs are quite staggering when establishing a 'virtual' laboratory, but once completed, the system architecture lends itself to propagation, in that it can be readily duplicated and manipulated to fit the needs of each student, with little cost other than maintenance. Chemistry laboratories tend to be rather large, in terms of student population, and as a result, students seldom receive individualized feedback (unless they seek it out). With a CAI Chemistry System, students are still identified by their anonymous Identification (SS) Numbers, but they are able to receive individualized support for their academic performance. However, while the student is able to gain the advantage of understanding a theory and its related mathematical concepts, they lose the positive reinforcement provided by instructors, proven to be a great learning stimulus.

Traditional chemistry laboratories are very time-consuming, in terms of introducing students to use of the apparati, safety procedures and hazardous of various chemical substances, and for 'Open-Labs', those where students are allowed to 'drop-in' anytime during a specific time span, the introductory lecture must be constantly repeated, slowing down

students and wasting time that they could be spending on other endeavors. By integrating tutorials on the use of lab equipment into the Web delivery, via the use of multimedia forms such as movies, animated GIFs, and graphics, students are able to obtain the necessary knowledge before entering the lab, thereby saving a large amount of time, and are able to decipher the technologies in a format that proves entertaining and educationally effective. Also, by placing these concepts on the Web, students are able to work at their own pace, allowing themselves enough time to effectively grasp a concept and, through the use of links and case studies, are able to view the concept in terms of real world scenarios, an aspect not clearly expounded in traditional laboratories or lectures.

While a Web-based system can provide numerous advantages, it must be accessible to students. Students must be able to use the CAI Chemistry System if they are to derive its benefits. The greatest trap in design any CAI or Web-based system is to become bogged down by the 'tricks' and techniques that actually hamper presentation and maneuverability. In order to test the usability of the site, student volunteers were recruited and asked to evaluate the site. Their feedback will allow us to determine what aspects of the system need improvement and/or refinement. The evaluation also entails the Intelligent Learning System, where we hope to record student perception of the system as related to the current Unix system.

2.1.2 Impairments

While most critics agree that Computer-Assisted Instruction (CAI) has its benefits, they feel that its negative impacts are too often overlooked in the eagerness of technological innovation. The most important hindrance of computer-aided learning is the loss of social

interaction. When students interact with each other, they can affect each others'

performances in a variety of ways; by competing against each other to come out as the best in

the class, by working on their own and ignoring other students and they can work together

for the benefit of all (Johnson, 12). Studies have shown that when students are taken out of

the classroom environment to which they have become attenuated they can suffer mood

swings, to either extreme. Students can become lonely, bored and frustrated without the

interaction of their peers. Conversely, some students, now in a situation void of peer

pressure, can excel when working on their own, at their own pace. Also, while students do

have the capacity to speak aloud while using the computer (limited only by environmental

constraints, such as computer laboratory rules) they lack the ability to verbally confirm and

orally explain what they have learned and achieve instantaneous verification of the pertinent

ideals. It is well know within psychological circles that discussion of material aids in

students' cognitive reasoning and retention. With no other students present, there is no

dialectic, no analysis and diagnosis of problems; the primary responsibility rests on the

individual student (Johnson, 12). The third constraint is the lack of social modeling. A

computer cannot teach learning strategies. Students can mimic the actions of their

compatriots in investigating concepts and thereby increase their own powers of cognitive

reasoning. The best match a computer can do is to provide a sequential order of steps. Yet

another limitation of CAI is the issue of reinforcement. Though frequent feedback is

encouraged in the design of CAI systems, no amount of approval from a machine is as potent

as the reinforcement of a teacher and one's classmates. The computer's responses are generic

and standardized, those from people are personalized and geared towards the individual

(Johnson, 13). These factors contribute to the creation of an "individualistic learning

situation". Students' seek out their goals independent of other students. Within "cooperative learning situations", students' achieve their goal only when every student within the group has succeeded. Students work together to help and encourage each other (Johnson, 14). Data indicates that cooperative education. "promotes greater oral discussion, of the material being learned; higher achievement; more frequent use of higher-level reasoning strategies; longer retention of the material being learned; higher achievement motivation; more positive attitudes about school, subject areas, instructional experience, and teachers; more positive attitudes toward classmates, regardless of differences in ability, ethnic background, and sex; greater self-esteem, psychological health, and collaborative skills." (Johnson, 15)

2.1.3 Benefits

The use of a multimedia system to promote a constructivist mode of learning has several inherent benefits that enhance the transfer of knowledge. Perhaps the most important of these is the availability of the resource; by making the system accessible over the World-Wide Web (WWW) its accessibility greatly increases. There is also the added incentive of little cost, as that associated with texts. The only major cost involved in a venture of this type is that associated with startup, once the infrastructure is in place, only maintenance and further upgrade are required. Then there is the added advantage of portability, in that the resource is available from literally any place in the world, that is equipped with the software and hardware requirements to 'get on' the Internet. Also, by making the system internet-compatible, students are engulfed in a medium that allows them direct access to a wealth of information, accommodated via the use of a common document protocol, Hypertext Markup Language (HTML) and document exchange protocol, Hypertext Transfer Protocol (HTTP).

2.1.4 What is Knowledge?

"Learning is not the acquisition of facts.", so states respected computer science author

Raymond Kurzweil in his The Age of Intelligent Machines (17). Computers are experts at

storing enormous quantities of facts, but it is an understanding of the inter-relationships

between facts and their subsequent implications that consist knowledge. For example, when

reading a novel or watching a movie, we are able to draw inferences about characters'

motivations and emotions fed on a knowledge base of human experience and interaction.

"Reason is the ability to draw deductions and inferences from knowledge with the purpose of

achieving a goal or solving a problem" (Kurzweil, 17).

2.1.5 The Constructivist Theory of Education

The constructivist mode of education is based on the idea that knowledge is produced by the

learner, via a series of questions, rather than from a text or teacher (Griest, 8). Under

constructivism, the student now has the responsibility of asking the questions, not

memorizing the answers to predetermined questions (Cunningham, 21). The student learns

by comparing and evaluating concepts; their thinking evolves to the creation of knowledge.

Students, when reading and taking notes from teachers and textbooks, are not practicing

cognition, they are learning but memorizing facts. The constructivist theory proposes that

students and teachers be equals within the classroom, simultaneously working towards

forming the course's knowledge base (Shores, 7.1). Textbooks are tools, serving as

authorities on the topic, but restrict thinking to simple, fact-oriented questions (Cunnigham,

30). Textbooks should be used as resources and not as the sources of knowledge. Instead of

knowledge taking a one-directional path, it becomes bi-directional, a process facilitated by

proper design of a computer-assisted instruction system (Griest, 8). The computer allows the shift of instruction from the "transmission model", where teachers use texts and lectures as the conduits of knowledge transfer, to the "transaction model", where meaning is transferred via a direct interaction (Griest, 8). Students were being taught from a system outside of themselves, and either the message, its source, mode of transport or the receivers needed to be changed because this system was not effective (Cunningham, 20).

2.1.6   The Seven Commandments of the Construction Process

1. Provide experience with the knowledge construction process: All aspects of our world make sense to us because we have had a lifetime of exposure to them and they have become integrated into our own knowledge base. Similarly, students are expected to construct their knowledge by comparison of different points of view and perspectives, and then comparing them to the real world. For example, when visiting a foreign country, one may not understand their customs, but upon examining the ritual and the circumstances surrounding the situation, one may determine that the action was actually a greeting, after comparing the factors to one's own culture (Cunnigham, 22).

2. Provide experience in and appreciation for multiple perspectives: Before anyone can assume a position on a particular issue, that must familiarize themselves with the facts surrounding the issue and expose themselves to the bank of views on the particular issue. Each stance must be assessed to evaluate its adequacy and relatedness to the person at hand. The central theme of this tenet is the acceptance of different views and the dialogue of those difficult to resolve, such as racism, sexism, etc., rather than the blind acceptance of a position as defined by a text or a teacher (Cunnigham, 23).

3. Embed learning in realistic and relevant contexts: An important factor in how students learn is the application of what they learn to real-world scenarios. More than learning the facts, the student must be able to see the interrelationships of these facts when applied to the real world. For example, a student may be able to determine when two trains will meet, but cannot determine how long it will take to get to their grandparents' home when they must account for stop-lights, traffic, on- and off-ramps, local and highway speeds, etc. (Cunnigham, 24)

4. Encourage ownership and voice in the learning process: Students have become used to not thinking, that is, not creating ideas of their own. If students can create a dialectic of ideas (see tenet #2) then they can express their views and they can gain respect for their intelligence and feel responsible for it, empowering them to take greater control of their lives. Students will see that in order to gain greater control of their lives, they must gain greater control of their thoughts and of their learning (Cunnigham, 25).

5. Embed learning in social experience: Every human being has a different perspective on their environment and this view is (partially) dependent on social interaction. A child, trying on his own, will have a difficult time learning, but when working with a teacher, is able to learn at a greater rate, and at an even greater rate in group scenarios. However, each child has different needs, as unique as they are themselves, hence the solution is to create a classroom culture where sharing is prioritized, under the influence of the teacher. The discussion that occurs is among the student, his/her peers and the teacher creating a social environment which fosters communication and dialectic. Learning thereby becomes a more relaxed activity(Cunnigham, 26).

6. Encourage the use of multiple modes of representation: This tenet more than any other

relates directly to the use of a multimedia system. Instead of treating these extraneous sources as secondary, they should be integrated into the learning paradigm. For example, the multimedia system provides students with visual and auditory references, and possibly other similar scenarios that present a particular topic. Students not only become engaged in a variety of inputs, some more closely related to the real-world than other, but can also determine which ones have the most merit (Cunnigham, 27).

7. Encourage self-awareness of the knowledge construction process: If students are to succeed using the construction system, they must understand how the entire theory works. The end goal is to make students aware of the 'constructedness' of their existing knowledge and the application of that base to the addition of further knowledge. Since our knowledge bases are formed by complex interactions of subject areas, students who have undergone this 'epiphany' would require numerous teachers for 'one' subject. For example, in learning about the history of an ancient culture, students might require input from geologists, geographers, climatologists, even mathematicians (Cunnigham, 28).

2.2   Design of a Multimedia System

2.2.1   Interface Design

The general school of thought on the design of multimedia interfaces advocates the standardization of the utilization of videos, graphics and animation, text, and feedback. The design of the user-interface can affect a student's learning time, speed, error rate and satisfaction (Thibodeau, 84). The use of these accoutrements should enhance and magnify the learning experience, but designers should be wary of becoming caught in the trap of using so many images, graphics, etc that the screen becomes cluttered and confusing to the user;

white space is very important to the user, especially those with smaller monitors. There is also the tendency to use these elements simply for their decorative powers and not their utility.

2.2.2 Movies

Movies allow learners the opportunity to enforce the concepts they have learned in textbooks through visual representation. In terms of videos, close-ups should be used to indicate items of importance while wide-angle shots should be used to provide a scope of the realm and fix frames of reference. When new items are introduced, they should be focused on long enough to allow the user to identify and chronicle the item. There should be no distracting or jerking movements; the viewer's eyes should be centered on the area most lit. If the activity presented is a simulation of a series of steps that the viewer would have to replicate, for example, the use of a spectrophotometer, the steps should be performed as closely as possible to the actual procedure, and presented from a first-person point-of-view, that is, from the perspective of the viewer. Video and audio have proven an effective combination in the transfer of knowledge and the learner is stimulated via two sensory pathways. However, one should be cautious in not using inappropriate audio or video elements that may be misconstrued, especially those used solely for aesthetic purposes (Thibodeau, 82).

2.2.3 Graphics

Graphics are especially useful in highlighting key points or providing a visual reference for a concept. Graphic objects are usually sharper, in terms of pixel density than movies, and are

thus more visually appealing, but lack the descriptive powers of movies. As with movies, basic social stereotypes should be avoided, in terms of race, ethnicity, sex, religion, etc. Humour should be tackled cautiously; while it may stimulate interest and promote memory, it can also cause distraction (Thibodeau, 83).

2.2.4 Text

Text is the most common method of transferring information. The major problem that text poses is in its layout, if it too closely resembles the textbook, the student is not engaged. The amount of text presented on the screen should be limited, especially since it takes the average person more time to read text on a computer screen. Reading text off a computer screen is 28% more difficult than reading from a book. Naturally, standardized form requirements should be taken into consideration; left justification, centering of titles and headings, use of upper case, bolding, italics, etc. Once again, there should be enough white space on the screen so as not to overwhelm the reader, and to separate sects of information. Numbered or bulleted lists are more useful and less eye-intensive than block paragraphs. Blinking text should be used sparingly, oversaturating the screen with attention-getting devices reduces the overall impact. Body or text intended to be directly read should never blink. Text colours and font selection can be useful in highlighting certain components, but the user's terminal characteristics should be taken into consideration, for such factors as lighting, monitor size, etc. (Thibodeau, 84).

2.2.5 Feedback

Providing immediate feedback is one of the most integral aspects of designing a system such as the one in question. A summary of each unit should be provided along with a review section. By switching between practice and summary, the learner is kept motivated and interested. Questions should be presented every 3-5 screens to break the monotony, and to immediately test the student on the recently acquired knowledge. Questions should be structured in such a way that the user is not simply reciting the text, but utilizing what he/she has just learned. By structuring the questions in this matter, the student "discovers" information rather than memorizes facts (Thibodeau, 84).

CHAPTER 3

SYSTEM DESIGN

3.1   Introduction

The DISTributed Intelligent Learning System (DISTILS) is designed to meet the needs of

freshman General Chemistry students and faculty. The system encompasses all aspects of

General Chemistry, from the basic concepts, mathematical formula, application of these

formulae and concepts, especially in the Pre-Lab Exercise, and multimedia exercises

showcasing the methodology of the laboratory. By using the Web as the mode of delivery,

we are able to incorporate the range of JAVA and the affordability of multimedia systems,

and allow for ready manipulation and expansion, especially available due to the layered

design of JAVA-ORB backbone.

3.2   Sequence of Steps

Upon accessing the site (http://bengu-pc2.njit.edu/trp-chem), students can choose any node

of knowledge, that is, the chemistry text, chemistry lab, Pre-Lab Exercise, Pre-Lab Quiz or

the Case Studies. If a student has never explored the site before, he/she would first need to

examine the chapter related to his particular subject area, and therefore he/she would click on

The Science of Chemistry. From there, the student would be required to choose the

particular chapter, of the six, that best suits his/her needs. Within the chapter text are several

links to pages to clarify concepts addressed. The chapter is also interspersed with images,

videos, animation, and other such multimedia elements. At the end of the chapter, students

can advance to the Chemistry lab and the subsequent Pre-Lab Quiz or access them via the Homepage. They can also access the Case Studies, with real-world scenarios, directly from the Homepage or from the Chemistry Lab. Students can also access the Help Page (http://bengu-pc2.njit.edu/trp-chem/help.html) at any time, either directly from the homepage or from within the Pre-Lab Quiz or Pre-Lab Exercise.

3.3   System Architecture

The system is designed with both faculty and students in mind. There are four modules within the system, the student model, the faculty model, the user interface and the learning and training model. The student interface allows individual accounts with password protection and allows instantaneous grading of student work. The faculty interface allows for the creation of new questions and new labs. Faculty are also able to review student progress and grades through their own individualized, password-protected account. The user interface component includes the Pre-Lab Quiz and Pre-Lab Exercise. The learning and training models coordinate the activity between the system and the user.

The intelligent learning system is designed to improve student performance and learning, over a time period. The system evaluates the student's progress, in terms of which question he/she answers and accordingly chooses a specific subsequent question. This is designed to replace the interaction between student and teacher and aid the student in passing the quiz, called a study-buddy. Students are provided with instantaneous feedback, that is, upon completion of the numerical question or multiple choice the student need only hit the SUBMIT button to view his/her performance. They then have the option of retaking that particular section.

The system is designed to maintain records of each student and design his/her quizzes accordingly. When a student first logs in, his/her full name, identification (SS) number (to uniquely identify each student), email and password are all saved. If an account has already been created and the student cannot remember his/her password, the quiz will automatically shut down after three unsuccessful logon attempts. Once they attempt a numerical question, regardless of the outcome, a character denoted such is stored within a database. This character ensures that no further randomization of data occurs. Fields are also created to store random numbers and answers, since each student receives the same numerical question with different numerical values. These fields store the numerical values so that, if the student needed to stop midway, they could logon again and pick-up where they left off. The students can email the problem to themselves to solve at a later time, and can also change their personal information via the information tab. Faculty can access a grade panel which stores the student's results, the number of attempts and the average number of attempts of all students in the class to pass a particular lab's quiz. The quiz and exercise are centered around the chemistry knowledge base, the basic theories and ideas that the students must know in order to complete the numerical question. Within the database, there are three major categories comprising the Declarative Knowledge; the Knowledge Type which encompasses principles such as Atomic Weight, the Know Object which would be the element whose atomic weight we are investigating, and a Description field. The intelligent learning system checks where each student has made an error and finds the corresponding step within the calculation where the error occurred and prompts the student with the respective concept. There is an inherent knowledge structure built into the system, similar to a tree. For example, in order for a student to know the molecular weight of potassium acid phthalate,

they must first know the correct formula, then the individual atomic masses. Each level is numbered and related to each lab so that they can be easily referenced.

The system also includes various case studies that show real world applications of various chemical principles, and presents multi-node access, via numerous links to various chemistry-related sites. The case studies also link directly to the fundamentals of chemistry presented within the main text of the site.

3.4   Help Page

The Help Page (http://bengu-pc2.njit.edu/trp-chem/help.html) was designed after receiving the results of student feedback, and thus constructed with the concerns of our subjects in mind. The page opens to a brief description of the aim of the Chemistry Web site, and a table that should be legible on even the smallest of monitors. The table contains a brief synopsis of each aspect of the site and a link to a fuller description of the component, incorporating various colored graphics. At the end of each description is a link back to the Table of Contents. The Help Page can be accessed from the main page or from the Pre-Lab Quiz or Pre-Lab Exercise.

CHAPTER 4

THE PRE-LAB EXERCISE

4.1 Introduction

In order to make students as comfortable with the system as possible and in an effort to encourage their explanation of its assets, the Pre-Lab Exercise was developed. Similar to the Pre-Lab Quiz in its numerical question structure, the Pre-Lab Exercise tests the students' understanding of principles and formulae associated with the lesson in question. However, the Exercise is significantly different in that it offers step-by-step assistance, as a "study-buddy". As with the Pre-Lab Quiz, the student is presented with an experimental situation and a set of given data from which they are to calculate the required information. If at any point in the calculation they become 'stuck' or confused, they are able to utilize the system's features to aid them in their efforts

4.2 Concepts

In solving the Numerical Question, the student must have mastered the requisite technical knowledge. If he/she has any shortcomings, whether in the concepts or mathematical areas, the system is designed to address their specific needs. For example, if a student were unfamiliar with the concepts of an endothermic reaction and this concept was included as an element of the numerical question the student would be at a loss. Luckily, he/she can follow the HELP link back to the specific portion of the Chapter that dealt with that concept in detail. The student can then reevaluate the concept as it relates to the question at hand.

Furthermore, since the student has been returned to the sanctuary of their web browser, they can also examine our section on real-world scenarios for an understanding of how the particular idea relates to the non-academic world, of decidedly greater significance than lab simulations.

4.3 Mathematics

Even if a student understands or at least can identify a concept, they may not necessarily be able to apply that concept to solving a problem, which is of the utmost importance when operating in a real-world scenario. However, since every student is different and every problem has multiple parts, some may have more problems with one part than another. Hence the system has been designed to incorporate these incongruencies.

There are several levels of understanding that must be attained for successful completion of a problem to occur. For example, if a student were asked to calculate the molar heat of neutralization for a particular experiment, they must attack the problem in a logical and sequential order. First, the student must be familiar with the terminology and concept of Molar Heat of Neutralization and therefore must refer back to the Chapter should they have any problems with this particular aspect. Second, even if a student understands the concept, they must understand how it applies to the task at hand. Usually, if the student is able to deduce which formula to use (or manipulation thereof) and more importantly why to use that formula, they are able to more successfully attack the problem. Third, simply having the right form of the formula does not guarantee success; the student must be able to deduce the value of the variables, that is, 'what goes where'. Simply stated, the student must know what values to plug-into the formula. He/she must be able to identify these values, their units

and their relevance. However, not all values for formulae are presented within the Given

Data. As the student progresses through the system, their knowledge bases gradually

increases and thus in later lessons they are required to draw upon previously covered

concepts. Some of these concepts will, no doubt, come into play in determining numerical

values that comprise the central formula.

The student must first be familiar with the concept, its relation to the problem at hand

and its general use. Again, if they have any failings at this point they can refer to the

Chapter. The next step is to understand the proper formula to use, as it applies to the

particular scenario. If the student is unfamiliar with the elements of this step, they can hit the

"?" icon and, via a series of questions, by prompted for the correct answer. Note, the answer

is simply not given to the student, but by interacting with the student through their responses

they are able to deduce the formula. Next, the students must have values to plug-into the

formula. Again, the system's ingenuity comes into play; the student is prompted for each

element of the formula. He/she may be asked:

"What is the change in temperature of the water?"

If an incorrect response is received, they may then be asked:

"What is the initial temperature of the water?

"What is the final temperature of the water?"

"What is the change in temperature of the water?"

If an incorrect answer is still received, the student is then prompted with the correct answer:

$\Delta T = T_f - T_i$

Therefore, for each aspect of the problem, the student is able to determine what numbers apply.
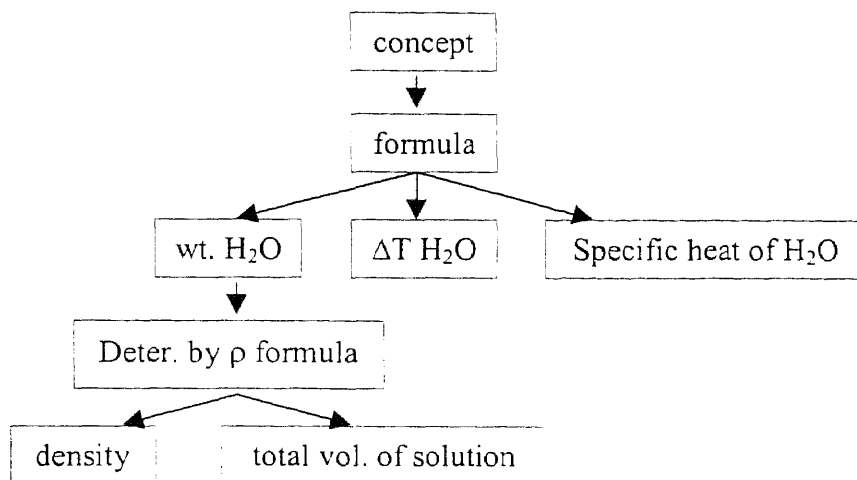
Figure 1 Knowledge Tree

The preceding figure (Figure #1) indicates the tree-like arrangement of required knowledge for one particular question in one of our Pre-Lab Exercises. The tier works on a step-down approach. The figure also indicates the manner in which the Pre-Lab Exercise is coded into the system. The first tier takes an optimistic approach that the student is capable of solving the problem but just needs to have the concept clarifies and will then be able to continue on their own from that point. The second tier assumes that the student needs greater assistance and therefore aids him/her via the deduction of the formula. As the student moves down the levels, he/she explores more rudimentary concepts that should have been mastered by this time and become deeply woven into the students' knowledge base

4.4 Creation of Numerical Problems

Numerical Problems are created separately for each chapter and specific to its content. The Numerical Question is also directly related to the lab practical in terms of the calculations and procedure involved. This is done to provide some sense of familiarity to the students, so that when they perform the lab practical, they would already have had exposure to a theoretical situation similar to the one they are currently experiencing. Therefore, it becomes necessary for the Numerical Questions to provide legitimate and believable answers. As previously stated, the Numerical Questions are randomized so that no two student receive the same question, however, to ensure that the answers fall within a reasonable limit, the questions must be designed accordingly.

In order to create the questions, we (the designers) must have an idea of the possible range of results that the student would obtain in the laboratory setting. Keeping this range in mind, the answers are first determined and set within this range. For example, if the lab required the student to determine the atomic weight of an unknown metal, and we knew that the unknowns the students would be given were Manganese, Iron and Cobalt, then we would now that their final answer, the atomic weight, would be in the range of 54-60 grams. Supposing that the second-to-last step in the lab practical involved weighing a specific mass of the substance that was the result of a chemical reaction, and we knew that the reaction would produce approximately 4 moles of the specific metal, then we would set the range of answers for that question to 216-240 grams. Again, if the third-to-last question required the student to determine the number of moles created in the reaction, we would set the range to 3.85-4.15 moles. We continue with this trend of 'back-calculating' the answers such that every answer is dependent on its subsequent answer. In so doing, we limit the randomization

to a reasonable range. We then proceed to create the Given information in the same manner, such that in falls within a range that would produce the final answers. However, since the computer knows the final answers, mathematical speaking, as we move 'backwards' the set of Given data that will produce the required result increases. For example, to obtain a result of 58 grams, one could divide 230 grams by 3.97 moles or 220 grams by 3.79 moles. This allows for increased randomized, but becomes very difficult to control, in terms of programming, with ranges, hence the use of equations. If we assign our final answer, atomic mass to the variable 'x' and our number of moles to 'y', then we can use these variables in an equation, instead of ranges, to determine our given values. Again, if a student logs on and the computer randomly assigns him an atomic mass of 58 grams, his Given data for the mass of product would be 'x*y'. Therefore, every student's results will be consistent with the chemical formulae they have learned and are applying while preserving the uniqueness of each question.

The Pre-Lab Exercise is not a gift. If the students have difficulty completing the numerical problem, upon exiting they are informed that they are not well prepared and perhaps should re-read the chapter. Also, the student is still required to complete the Pre-Lab Quiz before moving on to the laboratory practical.

CHAPTER 5

FIELD TESTING OF DRAFT COURSEWARE

5.1   Introduction

In order to properly evaluate the effectiveness of the transport medium, the multimedia

system, of the chemistry knowledge base, it was decided that conducting student evaluations

were necessary. Students were recruited on a volunteer basis from NJIT's General Chemistry

1 Lab (Chem. 124). Also, students from a local high school (Clifford J. Scott High School in

East Orange, NJ) who had had comparable exposure to the chemistry knowledge base, via an

Honors Chemistry Course, were offered the opportunity to volunteer for the survey. Students

were presented with a memo with contact information of the administrator should they

decide to participate. If interested, they were then presented with a Debriefing Form which

described the experiment, what they were expected to do, what would be recorded and what

reward they would receive. Students were then scheduled for appointments and informed of

the day, time and location. Once they arrived at the testing site, they were presented with the

requisite permission form. Students with them presented with the Instruction Sheet

describing the procedure and the location of certain pages and menus, and allowed several

minutes to peruse. Once confident and ready, students were allowed to navigate the site with

no assistance or interaction from the administrator, to simulate conditions in a computer lab

where, upon implementation, students will have to use the system unaided. The students'

time was recorded and they were then asked to complete the Evaluation Form. This

concluded the student's participation in the study.

5.2   Theory

Students would find the 'new' Pre-Lab more user-friendly, less frustrating and of greater

educational value than the 'old' Pre-Lab.

5.3   Materials and Apparatus

In order to evaluate the system, students had to be provided access to a computer with a high-

speed Internet connection. Students at NJIT were equipped with PC's running Windows NT

and access to the NJIT network. Students at Clifford J. Scott used a lab stocked with

Macintosh LC 575's and 580's, connected to an ISDN line.

5.4   Procedure

An internet-browser was opened prior to the student's testing. Students were then instructed

to browse to the aforementioned URL leading to the homepage. From there they were to

navigate to the Science of Chemistry and then to Chapter 4, *Properties of Solutions*, with no

assistance from the proctor. Students were to read through the entire chapter before heading

to the Chemistry Labs. They were then to select Lab Number Ten, The Spectrophotometric

Analysis of Phosphate and sequentially investigate all aspects of the section. Upon

completion, students were directed to the Pre-Lab Quiz and the navigation of its functions.

They were then given the option of investigating the Case Studies. Finally, students were

asked to complete the on-line questionnaire evaluating the site.

5.5 Results and Discussion

Table 4.1 Student Feedback

Item	Avg. Score	Max.	Min.	A	B	C	D	E	F	G	H
Rx. to the system	4.625	6	4	5	5	6	5	4	4	4	4
Rx. to the system	4.250	5	4	4	4	5	5	4	4	4	4
Rx. to the system	4.375	5	4	5	4	5	5	4	4	4	4
Rx. to the system	4.250	5	3	3	5	5	5	4	4	4	4
Rx. to the system	4.375	5	4	4	5	5	5	4	4	4	4
Readability of Characters	4.625	6	3	3	5	5	6	6	3	4	5
Screen Layouts	4.875	6	3	4	4	6	5	6	5	3	6
info. On Screen	4.250	7	2	4	2	7	5	7	5	2	2
arrangement of info	4.875	7	1	4	7	5	7	7	4	1	4
next screen seq.	3.875	7	1	4	1	5	7	5	4	1	4
back to prev. screen	5.500	7	3	4	7	7	7	3	7	3	6
position of instructions	4.000	7	1	4	2	5	7	5	2	1	6
msg.	4.000	7	2	4	3	5	7	2	4	2	5
comp. Info.	4.125	6	1	4	1	5	6	5	4	5	3
time between operations	4.750	7	1	4	5	5	5	7	5	1	6
learning to operate	4.500	7	2	4	2	7	5	4	3	7	4
getting started	4.750	7	1	4	6	7	7	1	4	7	2
time to learn	4.500	7	1	4	4	7	7	1	4	6	3
exploration of features	5.000	7	3	4	6	7	6	3	4	4	6
tasks straightforward	4.125	6	2	4	3	6	5	4	3	2	6
undo operations	4.125	6	1	4	6	5	5	1	4	2	6
feedback	3.875	5	3	4	3	4	5	3	4	4	4
correcting mistakes	4.125	6	2	4	5	4	4	2	4	4	6

The evaluation form (http://www.geocities.com/Area51/Lair/9624/evaluation.htm) consisted of both a

series of questions with Likert Scales and open-ended questions. All Likert Scales were

normalized (default) to '4', the average setting, and have '1' as the lowest or most negative

adjective and '7' as the most positive. The table above lists the responses of the eight

students to a series of twenty-three questions relating to and comparing the 'old' and 'new'

Pre-Labs. Unfortunately, none of our subjects were able to evaluate the 'new' Pre-Lab. The

system crashed when the sole NJIT student attempted to access the Quiz, and there was a

software conflict involving JAVA and the Macintoshes that disallowed the high school

students from accessed the Quiz. The students were, however, able to evaluate the current

site's contents and provide valuable insight into the restructuring and redesigning of the software.

If one were to investigate and draw assumptions based solely on the average scores, near all responses would fall about the average mark, '4'. This scenario seems applicable to the first five questions which expresses the students' overall response to the system along five pairs of adjectives; terrible/wonderful, frustrating/satisfying, dull/stimulating, difficult/easy, rigid, flexible. These responses suggest that the students did not find the overall system uniquely exciting or stimulating. The next two questions also hover about the average mark; readability of characters (hard/easy to read) and screen layouts were helpful (never/always), again suggesting that these aspects of the system did not particularly impress students. For almost all of the remaining questions, there develops a disparity in the opinions of students. For the next question, concerning the amount of information that can be displayed on the screen at one time (inadequate/adequate), three students ranked the system as '2', one as average and of the remaining four, two as '5' and two as '7'. There was an obvious dissimilarity in the opinions of students, leading to no derived consensus or meaning. Judging by the maximum and minimum scores, it would seem that a more extreme scenario occurs with the question regarding the arrangement of information on the screen (illogical/logical), but only one student rated this aspect below average, with most hovering around the '4' mark. Similarly, for the question concerning the next screen in a sequence, only two students marked the system below average. An interesting case involves the question concerning returning to the previous screen (the back function on most browsers), where four students rated the feature as 'easy' rather than 'impossible'. Therefore, these responses lend themselves to the deduction that students find this feature amiable, especially

concerning that only two students rated the feature as below average, and even then, as a '3'. No such clarity presents itself in the question measuring the position of instructions (inconsistent/consistent), as the marks are truly scattered, as with the question referring to on-screen messages. Other than one exemption, all students registered about average for the question relating to whether the computer was informing the user about its actions (never/always). Though most marks were around the average mark, one student registered very positively (acceptable) and one very negatively (unacceptable) for the question concerning the time between operations, as with learning to operate the system (difficult/easy). The next two questions again present extremes, in terms of getting started (difficult/easy) and the time needed to learn to operate the system (difficult/easy) student responses seemed grouped at the positive and negative poles with the remainder at the center, proving that no consensus exists whatsoever. For the question dealing with exploring the system's features (risky/safe), student responses (4) were either about average or (4) about the positive end. When asked to determine whether the tasks were straightforward (never/always) students responded within two degrees of average, that is, responses ranged between '2' and '6'. For the question concerning the ability to undo operations (inadequate/adequate), only two responses were below average, two were at the average mark and the rest were above average. Student responses were centered at average for the question concerning feedback (unclear/clear) and for the question concerning the ability to correct mistakes (difficult/easy). It is also interesting to note that Student A rated almost every aspect of the system as '4' while students D and H rated no element lower than '4'. Student F, on the other hand, save one '7' and one '2', rated all components about average.

The open-ended questions prove more useful in making determinations as to students' likes/dislikes concerning the system. Students appreciated the logical order and arrangement of information, calling the windows "attractive" and "not boring." However, they did complain that there was too much information presented, commenting that a possible feature may include a description of the Pre-Lab Quiz and the specific information (formulas, concepts, etc.) that the student would have to familiarize him/herself with before attempting. As a result, a synopsis, or bulleted list of key ideas will be presented within the lab chapter to be included at the start of each chapter. One aspect that was added in the midst of testing, a pop-up question box, was not received well by many subjects, who found it "annoying" and "frustrating". The window is intended to be an impromptu quiz to test the student's knowledge and understanding, but as one student remarked, if the student is already confused, a question randomly attacking him is not going to help. Based on this feedback, the self-assessment quiz icon is now placed at the end of each section as an optional feature. The next evaluation will test if students are able to notice this option and take advantage of it. One student did comment negatively on the overwhelming use of BACK buttons within various frames of one screen, not all of which returned the user to the same position. A back button consistent in shape has been integrated and a link to the homepage of the Lab. None of our subjects were able to experience the true multimedia experience of the courseware as the movies (AVI files) took too long to load and the students lost interest. While they enjoyed the use of images, they commented that the movies simply took too long to load and provided only a hindrance. We have since switched to the Real Audio and Real Video formats.

As part of their evaluation, students were asked to appraise the chapter that they read (Properties of Solutions). Their major complaint was the length of the chapter. Subjects felt that there was simply too much text and that it was difficult to read, especially on a computer screen, when an image or similar multimedia element rarely interrupted the monotony. Strangely enough, one student stated that the online text was "easier than reading the information in a textbook." One student remarked, "I would improve it by condensing the information." Another major problem was that in order to access the Chapter, students had to select it from a horizontal menu that appeared on the top of their screen and, due to the size of the monitors they were using, the top frame appeared very small, so much so that many students had difficulty finding the link. The horizontal menu will be removed from the separate frame, as a result, and integrated within the main window. Possibly due to the extent of the text, many students found it not only dull, but difficult to read, suggesting not only a strain on the eyes, but also the poor choice of fonts, color and style of text, as one student stated, "The print should be bigger and italics should not be used because they are hard to read." We have therefore decided to provide bigger fonts, minimize use of italics, and break the monotony of the text with a few more pictures, graphics, animation, etc. that seem to grab students' attention. Unlike the Chemistry Lab, students did not feel this chapter was ordered in a logical or sequential manner; many felt that additional instructions were needed if they were to proceed through the links as established or that the menus should be rearranged, simply stating that the "instructions should be placed in a better understanding, larger headlines, and a better order of sequence. At the start of each chapter, we shall present the students with an outline, similar to a Table of Contents, from which they can directly link to the related concept. Also, since this technique may make the chapter 'longer', we shall,

perhaps, limit each page/window to one to two topics, as in the Chemistry Lab window. The students did, however, prefer this form of delivery, praising its concept and purpose and the ability to quickly navigate through various aspects of the courseware.

If operating within a 5% Confidence Interval, with a population of 50, your sample size should be approximately 44 (Bernard, 79). Unfortunately, only nine students from NJIT's Chem. 124 responded to the memo. Of those, only three proceeded to schedule appointments for testing and only one student actually appeared for testing. Of the twelve students selected from Clifford J. Scott High School, eight students expressed interest and were sequentially tested over a period of three weeks, from November 10 through November 23. Therefore our sample size was limited to nine subjects (further reduced to eight as one, high school female, junior, was used to pilot-test the evaluation form), not nearly enough to draw a direct inference as to the effectiveness of the learning medium. Of the 8 students, 1 was an NJIT sophomore, male, and the other 7 were juniors and seniors from an area high school (Clifford J. Scott High School in East Orange, NJ). They were comprised of 3 juniors, female, and 4 seniors, 3 female and 1 male. As previously stated, students were unable to examine the Pre-Lab Quiz and Pre-Lab Exercise and thus were unable to provide feedback on these aspects of the system. The students were quite helpful, however, in providing feedback on the design, layout and other such qualitative aspects of the system, of no less worth than any quantitative measure.

APPENDIX A

SCREEN CAPTURES

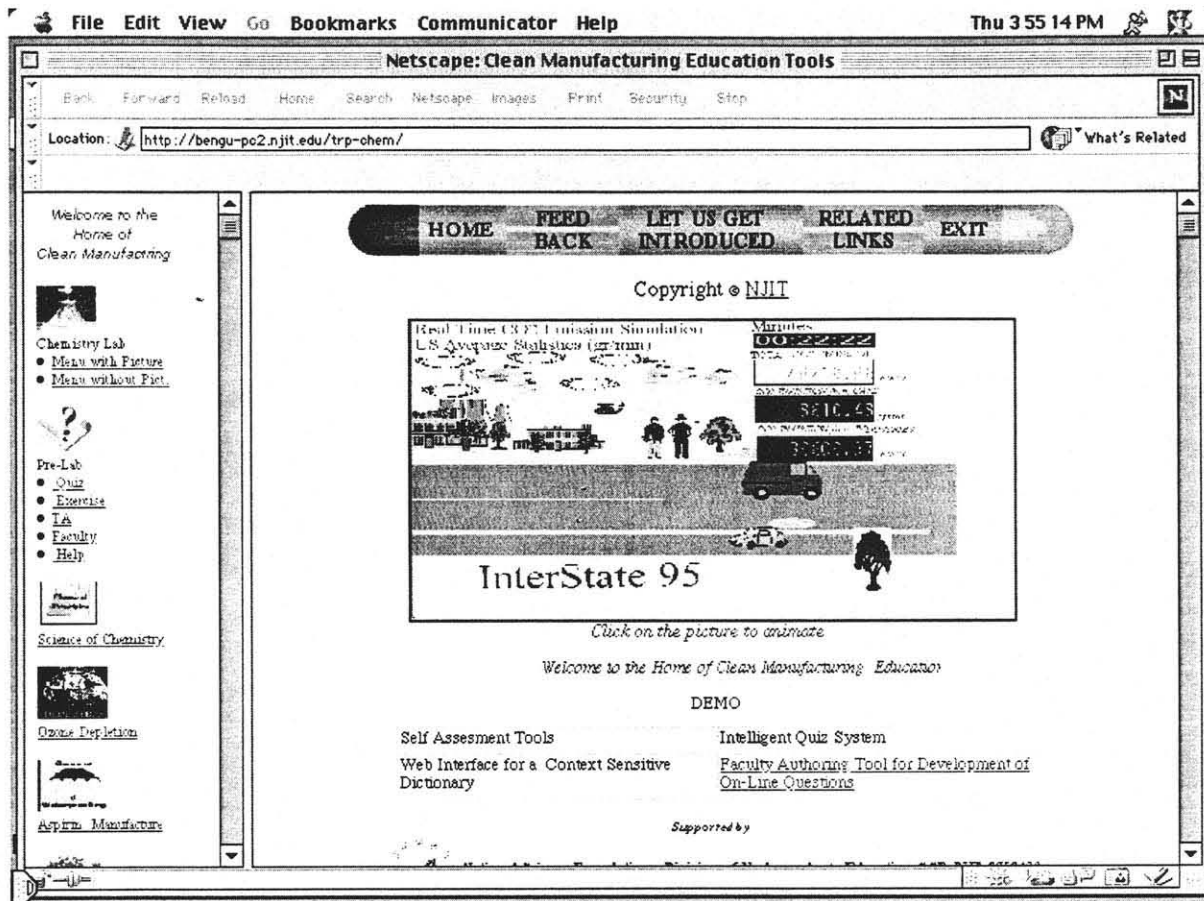**Figure 2** Opening Screen

File   Edit   View   Go   Bookmarks   Communicator   Help   Thu 4:19:08 PM

Netscape: HELP

Back   Forward   Reload   Home   Search   Netscape   Images   Print   Security   Stop

Location: http://www.geocities.com:80/Area51/Lair/9624/help/help.html   What's Related

HELP

Before starting the Chem- lab, you must pass all the questions, in the following order:
A) Numerical Question (1 Question): Try as many times as needed until correct.
B) Multiple Choices (8 Questions): Correctly answer 7 of 8 questions to pass. With each attempt, you will be given a new set of questions. You can access your grades by hitting the LAB GRADE button. You can also EMAIL the questions to yourself to print locally

Table of Contents   (Point for synopsis)

Figure 3 Help Page

KNOWLEDGE TREES

```
              ┌───────────┐
              │  concept  │
              └───────────┘
                    │
                    ▼
              ┌───────────┐
              │  formula  │
              └───────────┘
              ╱     │     ╲
             ▼      ▼      ▼
   ┌──────────┐ ┌──────────┐ ┌────────────────────┐
   │ Wt. H₂O  │ │ ΔT H₂O   │ │ Specific Heat H₂O  │
   └──────────┘ └──────────┘ └────────────────────┘
        │
        ▼
   ┌────────────────────┐
   │  Determination by  │
   │  Density Formula   │
   └────────────────────┘
        ╱          ╲
       ▼            ▼
 ┌──────────┐ ┌─────────────────────┐
 │ density  │ │ Total vol. of solution│
 └──────────┘ └─────────────────────┘
```

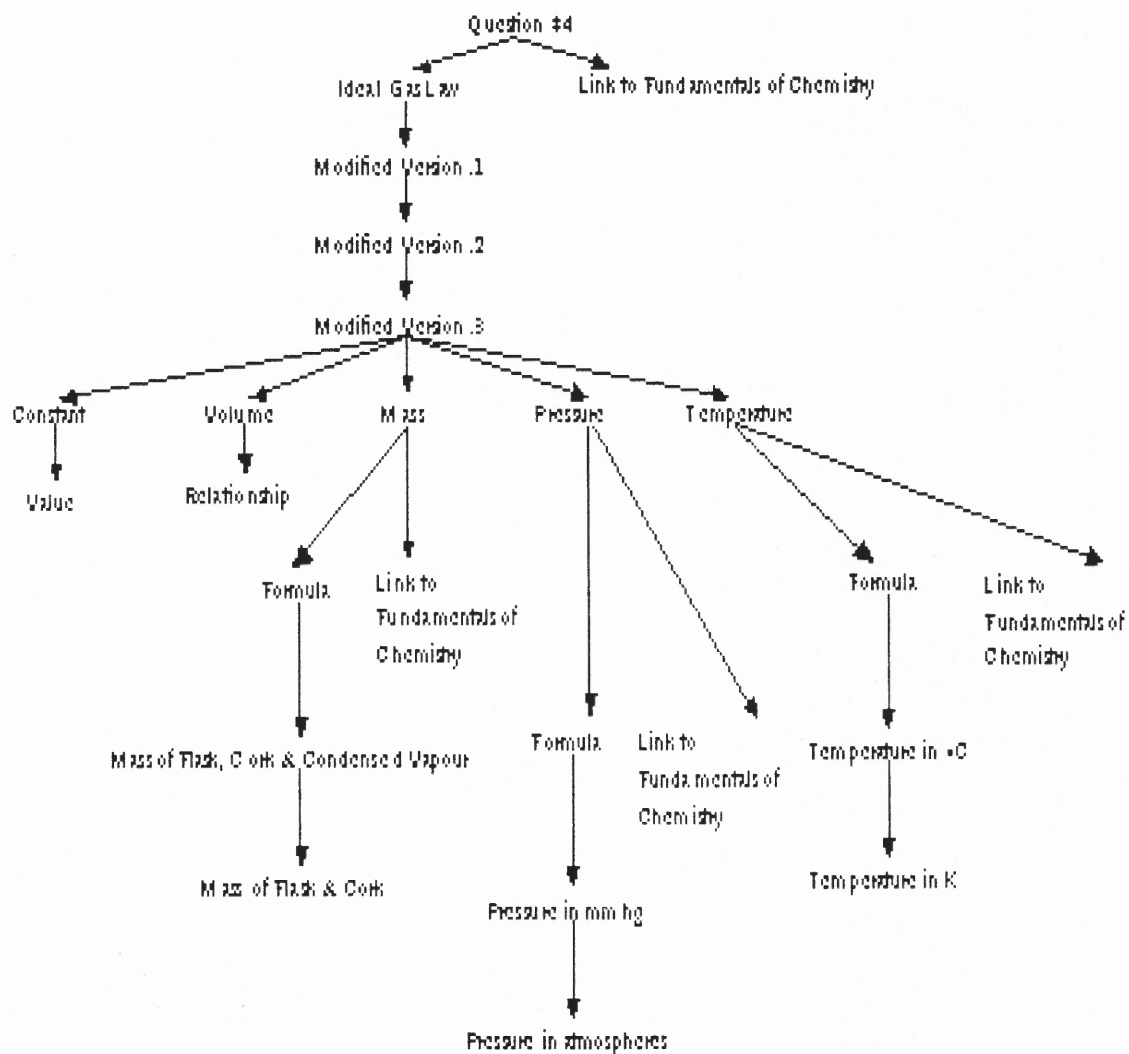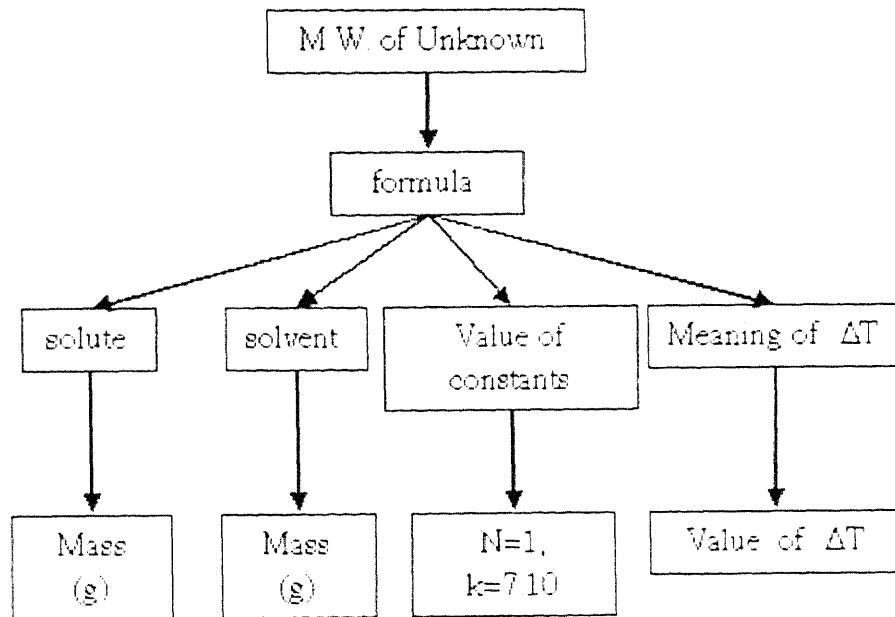**Figure 4** Calorimetry

Figure 5 Spectrophotometry

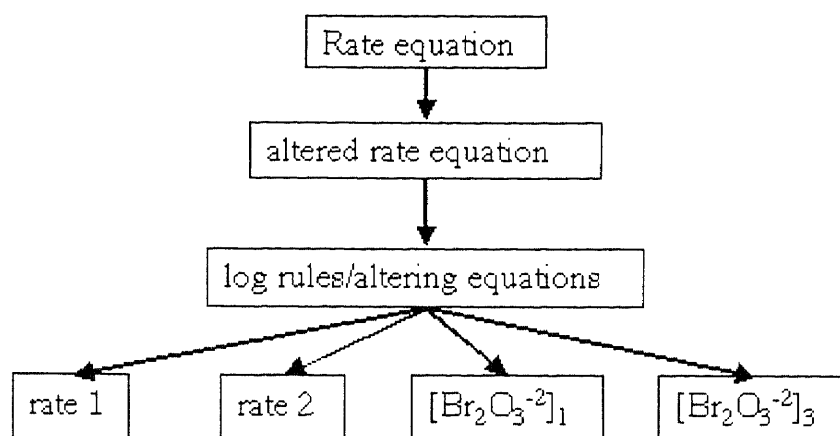**Figure 6** Molecular Weight of a Volatile Liquid

Figure 7 Kinetics

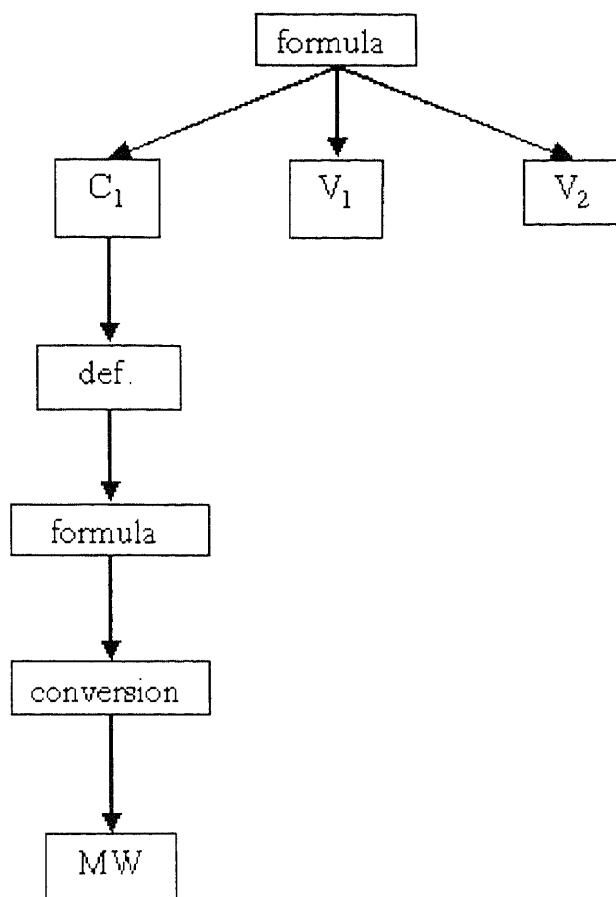**Figure 8** Molecular Weight Determination by Freezing Point Depression

APPENDIX C

EVALUATION FORM

Personal Information

Name:[   ] ID #[   ] Age:[   ]

Gender: ●Male ○Female Major:[   ] Degree Expected:[   ]

Year:[   ] ▲▼ ●Graduate Student ○Faculty ○Other

G.P.A.[   ] Last Common Exam Score:[   ]

Part 1: Computer Experience

1.1 Have you taken any computer courses before? ●Yes ○No

If Yes, list all the computer courses you have taken

before:[   ]

1.2 On the average, how much time do you spend per week on computers?

[   ] ▲▼

1.3 Of the following devices, software, and systems, check those that you have personally used and are familiar with:

☐Computer terminal	☐Personal computer	☐Laptop computer
☐Colour monitor	☐Touch screen	☐Floppy Drive
☐CD-ROM drive	☐Keyboard	☐Mouse
☐Track ball	☐Joystick	☐Pen-based computing
☐Graphic tablets	☐Head mounted display	☐Modems
☐Scanners	☐Word processor	☐Graphic Software
☐Spreadsheet software	☐Database software	☐Computer Games
☐Voice recognition	☐Video editing systems	☐Internet
☐CAD-computer aided design	☐Rapid prototyping systems	☐e-mail

On the scale, please select the number that most appropriately reflects your judgement.

1.4 How confident are you in using a computer?

[   ] ▲▼

1.5 How much do you enjoy using computers?

[   ] ▲▼

39

Part 2: Chemistry & Math Experience

2.1 Have you taken any chemistry courses before? (including high school, summer programs, etc.)

⬤Yes ○No

If yes, list all the chemistry courses you have taken:

[text box]

On the scale, please select the number that most appropriately reflects your judgement.

2.2 How familiar are you with the concepts of chemistry?

[dropdown]

2.3 How confident are you in the practical use of these concepts in the laboratory?

[dropdown]

2.4 Have you taken any mathematics courses before? (post-Algebra & Trig.)

⬤Yes ○No

If yes, please list all (ranging from Pre-Cal through Diff. Eq. and Stats.)

[text box]

2.5 How confident are you with using these concepts in your homework assignments?

[dropdown]

2.6 How confident are you with using these concepts in your labs?

[dropdown]

Part 3: User Reaction to Pre-Lab System

	'OLD' PRE-LAB	'NEW' PRE-LAB
Overall reactions to the system		
3.1	[dropdown]	[dropdown]
3.2	[dropdown]	[dropdown]
3.3	[dropdown]	[dropdown]
3.4	[dropdown]	[dropdown]

3.5 [▲▼]   [▲▼]

3.6 Characters on the computer screen

[▲▼]   [▲▼]

3.7 Screen layouts were helpful

[▲▼]   [▲▼]

3.8 Amount of information that can be displayed on screen

[▲▼]   [▲▼]

3.9 Arrangement of information displayed on screen

[▲▼]   [▲▼]

3.10 Next screen in a sequence

[▲▼]   [▲▼]

3.11 Going back to the previous screen

[▲▼]   [▲▼]

3.12 Position of instructions on the screen

[▲▼]   [▲▼]

3.13 Messages which appear on screen

[▲▼]   [▲▼]

3.14 Computer keeps you informed about what it is doing

[▲▼]   [▲▼]

3.15 Length of delay between operations

[▲▼]   [▲▼]

3.16 Learning to operate the system

[▲▼]   [▲▼]

3.17 Getting started

[▲▼]   [▲▼]

3.18 Time to learn to use the system

[▲▼]   [▲▼]

3.19 Exploration of features

[▲▼]   [▲▼]

3.20 Tasks can be performed in a straightforward manner

[▲▼]   [▲▼]

3.21 Ability to undo operations

[▲▼]   [▲▼]

The following questions are related to the Pre-Lab Quiz
3.22 Feedback on the completion of a sequence of steps

[▲▼]   [▲▼]

3.23 Correcting your mistakes

[▲▼]   [▲▼]

Part 4: Knowledge
4.1 How much have you learned from this Pre-Lab about this specific chapter?

[▲▼]

4.2 How much have you learned about the math involved?

4.3 How much have you learned about the theory involved?

4.4 How confident are you in what you've learned?

Part 5: Evaluation

5.1 What are your opionions of the HELP menu?

5.2 How much did you enjoy this learning environment?

5.2.1 as compared to the 'old' Pre-Lab?

5.3 How would you evaluate this program?

5.3.1 versus the 'old' Pre-Lab?

5.4 Name three things that you liked best:

1.

2.

3.

5.5 Name three things that you did not like:

1.

2.

3.

5.6 How would you improve it?

5.7 What are your opinions concerning the order, layout and sequence of menu

items?

5.8 General Comments:

WORKS CITED

1. Bernard, H. Russell. Research Methods in Anthropology. London: AltaMira Press, 1995.

2. Bhatt, M. "Resources on the Internet for Engineering Education." European Journal of Engineering Education 21(1996): 235-243.

3. Converse, Jean M., and Stanley Presser. Survey Questions: Handcrafting the Standardized Questionnaire. London: Sage Publications, 1986.

4. Cunningham, Donald J., Thomas M. Duffy and Randy A. Knuth. The Textbook of the Future. Bloomington, IA: Indiana University Press, 1996.

5. Griest, Gary. "You Say You Want a Revolution: Constructivism, Technology, and Language Arts." The Computing Teacher 12 (1993): 8-11.

6. Hedrick, Terry E., Leonard Bickman and Debra J. Rog. Applied Research Design. London: Sage Publications, 1993.

7. Johnson, David W., and Roger T. Johnson. "Computer-Assisted Cooperative Learning." Educational Technology 21(1986): 12-18.

8. Kalton, Graham. Introduction to Survey Sampling. London: Sage Publication, 1986.

9. Klockars, Alan J., and Gilbert Sax. Multiple Comparison. London: Sage Publications, 1986.

10. Kurzweil, Raymond. The Age of Intelligent Machines. Cambridge, MA: The MIT Press, 1990.

11. Rosenthal, Robert. Meta-Analytic Procedures For Social Research. London: Sage Publication, 1984.

12. Shneiderman, Bob. Designing the User Interface: Strategies for Effective Human-Computer Interaction. 3rd ed. Reading, MA: Addison-Wesley, 1998.

13. Shores, Richard E. "Developing Hypermedia Courseware Through Partnerships of Students and Instructors." Journal of Education for Business 71(1996): 214-218.

14. Solomon, Martin B. "What's Wrong with Multimedia in Higher Education." THE Journal 21(1994): 81-83.

15. Thibodeau, Pete. "Design Standards for Visual Elements and Interactivity for Courseware." THE Journal 24(1997): 84-86.

16. Weller, Susan C., and A. Kimball Romney. Systemic Data Collection. London: Sage Publications, 1988