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Reengineering the General Chemistry Laboratory Experience:
Use of an Intelligent Learning System

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1. INTRODUCTION

There are various ways to apply the power of modern computers to the laboratory experience in chemical education. Some have tried to use them to simulate the experiments that would be done in the laboratory, on the theory that dangerous, expensive or even impossible experiments can be simulated. However, most chemical educators agree that no simulation can truly replace the hands-on experience of the student in the laboratory. Therefore, we have chosen to follow a different path, using the computer to enrich, prepare, and assist the students both in the laboratory and before they come to lab. The software being developed at NJIT is available to the students in the laboratory and from anywhere they can access the World Wide Web.
It includes the following:

- ***On-line lab book*** with audio and video clips, animated diagrams of instruments
- **A *self-test system*** to allow students to assess their understanding
- **A *pre-lab quiz*** *system*
- An ***interactive tutorial*** **system** for aiding students who have difficulty with the pre-lab quiz, which simulates faculty-student interaction.
- **An *authoring facility*** for faculty to compose and edit questions in the pre-lab quiz
- ***Links*** to case studies, other background material and on-line resources
- A context sensitive ***on-line dictionary***, the semantic reader.

At present, the system contains twelve laboratory experiments, which we use in a one semester General Chemistry Laboratory course. These are:

1. Measuring the Density of a Solid and a Liquid
2. Some Non-metals and their Compounds
3. Water of Hydration
4. Preparation of Sodium Bicarbonate and Sodium Carbonate by the Solvay Process
5. Separation of Metal Ions by Paper Chromatography
6. Calorimetry: Experiments Based on Thermodynamics
7. Analysis of Acidic Substances by Titration
8. Molecular Weight of a Volatile Liquid by the Vapor Density Method
9. Molecular Weight Determination by Freezing Point Depression
10. Kinetics: The Clock Reaction
11. Spectrometric Analysis for Phosphate
12. pH, Buffers, and the Dissociation Constant, Ka

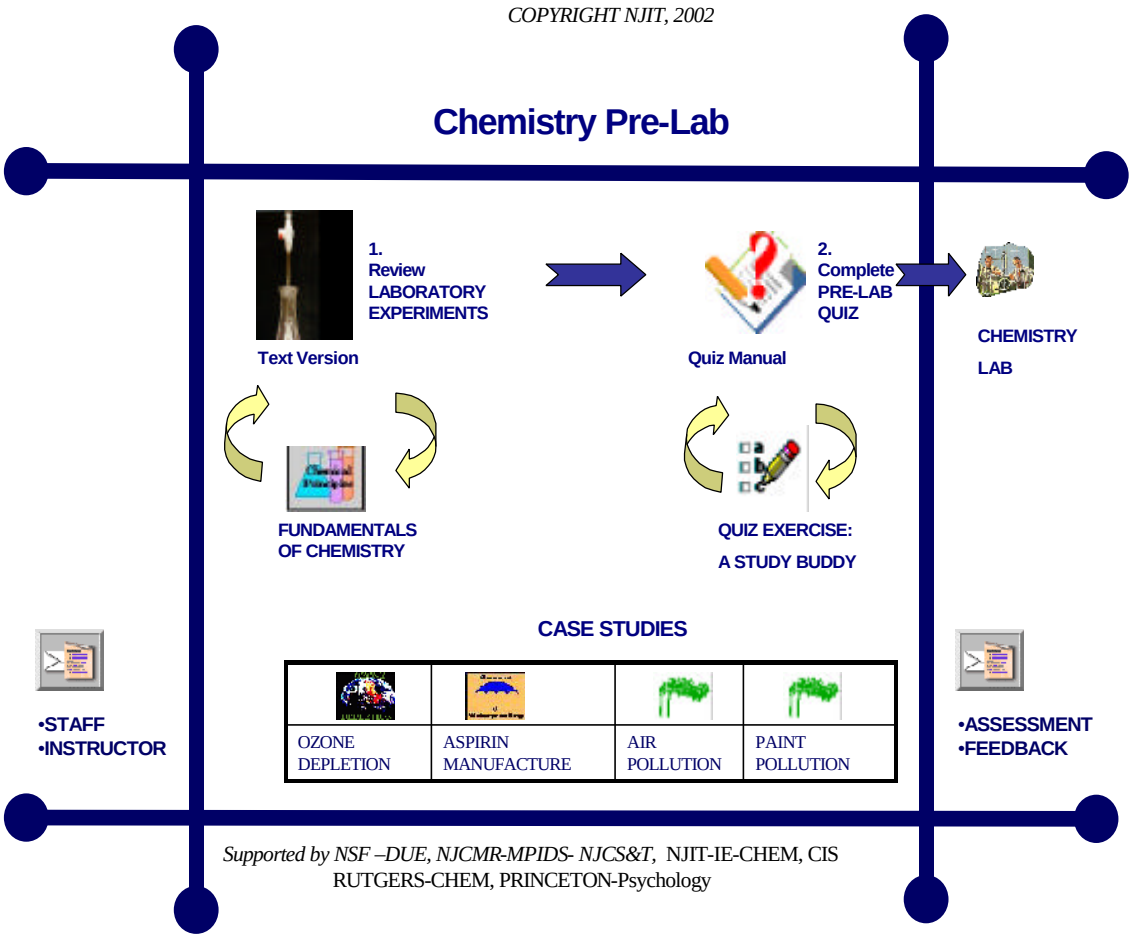

Figure 1. Entry to the Web Site of the Pre-Lab Chemistry.

- The on-line lab book not only provides the complete text, as is found in the lab book, but also multimedia enhanced items that cannot be readily presented in an ordinary book, such as audio and video explanations of laboratory techniques, and animated diagrams that show the operating principles of instruments such as spectrometers. The overall structure of the experiments in the program is formalized so that new ones can be added with a minimum of programming.

- The self-test system allows students to assess their understanding. At the end of each section of the lab text, as an option, a set of multiple choice questions are presented allowing students to check that they have understood what they have read, and focusing their attention on important concepts in the text.

- The on-line pre-lab quiz system is an important component of the system. Students are required to complete it successfully before arriving at the laboratory to perform the experiments. Each student's pass status is reported in real time to the laboratory instructor, so the student can be admitted to the lab as soon as the quiz is passed. This eliminates the need for manual disposition of pre-lab assignments just before a lab that is not graded until after the experiment is done. The system, now, allows to correct misconceptions before the experiment is carried out. The on-line quiz includes calculations that mimic those which will be done on the student's experimental data. The quizzing system can also be used for homework exercises. Since the students' work is recorded, faculty is relieved of a significant grading burden, while students still have the incentive to do the work. The fact that the questions and data are unique to each individual also significantly reduces the opportunity of copying of work.

- An interactive tutorial system for aiding students who have difficulty with the pre-lab quiz is also being developed. While students can request "live" help from the laboratory instructors in lab or by e-mail, an on-line intelligent tutoring tool (ITT) has been implemented. This tracks the students' previously demonstrated skills and mastery of particular topics and offers step-by-step assistance with the calculation. The 'intelligence' of this system tailors the tutoring to each student. It allows suggestions to be made which are more likely to address the student's difficulty, without repeating material which has already been shown to have been mastered.

- An authoring interface is available for the faculty to readily compose additional quiz questions, both computational and multiple choices, without doing any programming or writing software code. This option provides the adaptability of this system to accommodate individual faculty preferences in terms of how questions are posed and in what order they are expressed.

2. **THE SYSTEM: DISTILS, DIST**ributive **I**ntelligent **L**earning **S**ystem

Each experiment is discussed in DISTILS. The entire text of the laboratory manual is on-line. Each experiment is structured in standard with pages describing safety concerns, objectives, background material, apparatus, the chemistry involved, the experimental method, data and

calculations. Links to case studies and a feedback survey are also included for continuous improvement of the system based on the user feedback.

DISTILS aims to present a distributed collaborative learning environment to provide a holistic instruction paradigm for freshman chemistry laboratory. To achieve this goal, state-of-the-art information technologies such as the World Wide Web, Java and distributed object-oriented computing technology-CORBA, are utilized, and provide enabling infrastructure for DISTILS. The system also takes advantage of the AGENT technology. This learning environment essentially consists of a hypermedia version of general chemistry laboratory lecture, with various agents assisting students through the material during their learning sessions. The agents included are the:

1) Semantic reader,
2) Expert agents,
3) Student modeler,
4) Intelligent tutoring tool and
5) Adaptive lecture guidance (ALG).

The semantic reader provides context sensitive meaning for the words on the computer screen. The student modeler, expert agent and the ITT are components of the intelligent tutoring system. The expert agents store domain expertise. The student modeler assesses students' knowledge progress based on their performances in the on-line quizzes. The ITT coordinates with the expert agents and the student modeler to provide problem solving coaching on-line. The ALG cooperates with the student modeler and provides navigation guidance sensitive to students' knowledge status.

3. RESULTS

The software is nearly completed, with final editing of the courseware; final debugging of the software and testing by students are being carried out at the present time. The completion of this software will yield significant benefits to both the students and the academic departments. The on-line quiz capabilities allow checking that students have read and mastered the principles needed for understanding the experiment to be done before they come to lab. This minimizes the waste of expensive laboratory time. The software not only tests the students' understanding, but also provides on-line tutoring for those who are having trouble. The tutoring tool is unique in that it records each student's learning, and attempts to predict the trouble spot in the logic train, rather than repeating material that the student has already mastered. As soon as the final testing and editing is completed, we expect that the DISTILS program will be put into use at NJIT and also at Rutgers University, Newark. We are also looking into wider distribution, as well as using the overall structure with new material for use in other courses.

4. CONCLUSION

Although this system is originally designed for Chemistry, the open architecture of the system as well as the use of Industry software standards provides the flexibility and the reusability. Currently system is being adapted for other Engineering domains such as Simulation, Statistics, and Engineering Economics.

5. ACKNOWLEDGMENT

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