

Web Based Tutorials for General Chemistry

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I. Background

This proposal seeks to initiate the development and evaluation of web based tutorials for use in a General Chemistry course. The problems in teaching General Chemistry have been recognized nationally for some time now and are being addressed in multiple ways. Assessment of the problems at Southwestern leads us to propose the following approach to meet the needs of our students. The set of tutorials proposed here would allow students:

- to do more exercises without using a lot of class time
- to visualize three dimensional molecular structures and thus, develop chemical intuition
- to self-test which will assure that they have grasped the major concepts
- to perfect their problem solving skills
- to assess their understanding of the material before taking their exams in class

We hope that these tutorials will improve student learning overall and allow more students to succeed in General Chemistry, a foundation course not just for those interested in pursuing chemistry, but also for biology majors.

General Chemistry is a two-semester sequence that introduces the student to a wide range of concepts. This course, including both lecture and laboratory components, is typically a high enrollment course comprised mostly of freshman. Since this class is almost entirely comprised of freshman with wide variations in their high school background and level of academic preparedness, many students invariably find themselves in need of teaching resources that will bring them up to a par level with the class at large. The available web-based technologies, with their inherent self-paced and interactive nature and rich media options, provide a valuable tool for creating such a teaching resource. The web-based tutorial proposed here will allow students to monitor their understanding of the material and will allow the professor to reinforce fundamental chemical concepts.

In order to succeed in a chemistry course, students must be able to apply chemical concepts to different problems. To achieve this, the student must acquire factual information as well as understand numerous concepts. Due to the voluminous material, a student who does not accomplish this when the material is presented in class can fall behind and never catch up. The instructor does not have enough class time to dwell on any one topic long enough to ensure that every student has thoroughly understood it nor is there the time to test frequently enough to track how well they have understood the material. Rather, this is done when the student takes the

exam at which point it is too late for the student to earn a good grade or for the instructor to review material covered a couple of weeks earlier. It is particularly important for a first year student to adopt good study skills that involve working on this course at a steady pace throughout the course rather leaving it until just before a quiz or an exam. The proposed tutorials will be designed to ensure that students adopt such skills.

The immediate goal is to develop a set of questions for each chemical topic with which students seem to have a difficult time understanding. For example, one tutorial would address the rules that describe how to name molecular and ionic compounds. This would be followed by several problems that have the students naming and identifying compounds. The program would give instant feedback and allow them to tackle more problems than are usually found in the General Chemistry textbook. A longer-term goal is to develop more extensive tutorials that relate chemistry with more direct applications. These tutorials will guide students through a particular chemical concept that relates to everyday life. From these guided tutorials, they will then have to use the information to address specific questions. In addition, the project described here can be extended to the laboratory section of the course so students will have a better pre-laboratory experience.

This grant would allow us to develop the basic skills needed to set up a web based tutorial and will serve as a stepping stone to ultimately teach students how to problem solve. We have chosen to develop our own tutorials rather than use commercially available ones or those that faculty at other institutions might have designed for several reasons. Our long term goal for these tutorials is that they present the theory or concepts, make connections to everyday experiences whenever possible, provide animations when appropriate, and ask the sort of questions that make the students think about the concepts involved. They are not meant to be simply a database of exercises, self-tests and quizzes. Our survey of available materials did not provide us with any that we would be enthusiastic about. Furthermore, tutorials designed and developed in-house have the advantage that they would directly address the needs of our students and would allow our faculty to modify them to meet their individual needs.

II. Description

Initially, we will develop four tutorials: the first two will be used in the first semester and the other two in the second semester of General Chemistry. Each tutorial will cover an important scientific theme that is typically taught in the first year and will have some or all of the following components.

- General theory and explanation of major concepts.
- Each tutorial will be divided into smaller units based on individual concepts or ideas requiring short spans of time so that students would not be discouraged. The units will be designed to increase in difficulty.
- Animations will be included whenever appropriate.
- Specific problem-solving skills that need to be acquired.

- Practice exercises with instant feedback that help clarify and improve understanding of the material presented. These can be divided into varying levels of difficulty to suit the different backgrounds in preparation and different abilities of the students.
- Self-tests on each unit with instant feedback at the different levels of difficulty to allow the student to gauge their progress towards the required level to be attained.
- Quizzes that would allow the instructor to assess student performance as well as for assigning course grades.

The four tutorials are proposed to cover the following topics.

- 1. Nomenclature.** Learning the rules for naming compounds is an essential part of learning the vocabulary of chemistry. It is something that will be used in all chemistry courses that a student would take. Students tend to resort to memorization only to forget as soon as the exams are over. A reasonable amount of practice leads the student to understand the reasons behind these rules, thus being able to name compounds more meaningful. This is a topic that would be very suitable a computer-based tutorial.
- 2. Solubility and reactions in aqueous solutions.** Identifying types of chemical reactions and predicting their products is relatively easy for the experienced. However, the novice first year student enrolled in General Chemistry must learn to apply a set of rules. For example, whether a precipitate will form in this reaction depends on application of solubility rules. Whether a reaction involve electron transfer requires calculation of oxidation states. This topic is also amenable to computer-based learning.
- 3. Molecular geometry.** Visualizing three-dimensional structures of molecules is an integral part of 'doing chemistry'. It is also a skill that one acquires through working with models, hand-held or computer-based. Prediction of geometries is based on application of a set of rules beginning with keeping an electron count using what is known as Lewis dot structures to using rules based on minimizing electron repulsions to predict the shape that a particular molecule would adopt. Considering the ease with which three-dimensional structures can be manipulated on a computer, this topic is ideal for the tutorials we propose.
- 4. Intermolecular forces.** Being able to explain several observed properties of solids, liquids, and gases require an understanding of how molecules or ions interact with each other. This topic is particularly suited for computer-based tutorials because the behavior of atoms, ions and molecules individually or collectively is responsible for the observed properties at the macroscopic level. The connection between the macroscopic and the molecular worlds is important for understanding the importance of chemistry in our everyday lives. It is also something that is particularly difficult for students. In this tutorial, various concepts in addition to how molecules interact with each other can be explored. For example, an understanding of electronegativities and bond polarities explain why some molecules are polar while others are not. Polarities of molecules in turn affect properties such as boiling, melting, and solubilities, to mention a few. Computer animation can also enhance a tutorial for this topic helping the student visualize the process occurring at the molecular level.

III. Timeline

Spring 2004: During the spring semester we would begin the creation of a database of questions and exercises. With anticipated funds from the Partners in Pedagogy Program at Southwestern, we will be able to employ student(s) to begin the data entry process.

Summer 2004: In early summer (second half of May), we, the applicants will concentrate on developing skills in computer technology that will allow us to create the web-based tutorials of the type that we envision. While we are currently able to create web pages, we need to acquire skills to design interactive web pages and animations. During June and July, we would prepare the tutorials, integrate the database of exercises, prepare and integrate self-tests and quizzes.

Fall 2004 & Spring 2005: Implementation of the web-based materials and assessment of the project. Our goal is to expand the project to include tutorials on all major concepts covered in the two-semester sequence of General Chemistry. After reviewing the results assessing the implementation of this project, we would begin planning for the next stage.

Summer 2005: Revise the first batch of tutorials as necessary. Begin work on the next batch.

IV. Technology

Computers and software for web design are the only major requirements for the development of this project.

V. Other support

This project will require creation of a database consisting of questions, problems and exercises. Student help will be used for routine data entry. Consultants are available for more challenging aspects of the project such as the creation of interactive web site and animations. Dr. Glenda Carl, Associate Professor of French and Latin, is a resident consultant in the Partners in Pedagogical Technology Program at Southwestern University. The staff in Information Technology Services are also available to provide training and for consultation on specific issues. Southwestern University will also provide the necessary space on the campus server.

VI. Learning outcomes

The overarching goal of this project is to improve student learning and increase the chances of success in General Chemistry regardless of the level of preparedness of students in high school. With this computer-based exercises, home works, self-tests with instant feedback, and quizzes, we hope to accomplish this goal through a series of steps briefly described below.

- Initial self-test with instant feedback will gauge the level of understanding based on the high school preparation of the student prior to introduction of a topic or concept. A poorly prepared student will have the opportunity to review the basics, get help from the instructor, and use the computer-based practice problems and exercises to catch up.

- After the introduction of the concept, the students would use these computer-based exercises designed to enhance conceptual understanding as well as develop problem-solving skills.
- Multiple levels of difficulty in the tutorials will allow students to advance at their own pace incrementally. A self-test at each level with instant feedback will help the student gauge when s/he eventually reaches level expected by the instructor.

This project proposes a cycle of practice and self-tests will ensure that every student has the opportunity to succeed in General Chemistry. In principle, this process could be instituted for each topic introduced in this two-semester course. If the level of understanding of each concept can be assessed prior to moving on to the next, the building of knowledge will occur on a solid foundation.

VII. Curriculum

Integration of this project in the curriculum is expected to be seamless. Both applicants teach General Chemistry on a regular basis and will design the computer-based materials to replace and supplement what they currently use. Since almost all students these days own computers, and the dormitories are hard wired, access is not an issue. The materials will be web-based so that the students would be able to use them from their rooms.

VIII. Assessment

The assessment of the project will be three-part and conducted using surveys. One part will assess the impact on students' attitudes and study habits; the other part will assess whether the student learning is improving.

1. Some examples of what attitudinal surveys will be designed to investigate are:
 - whether the convenience of computer-based tutorials and instant feedback resulted in the student spending more time on practice problems on a particular topic before moving on to another;
 - whether self-testing at each level of difficulty before progressing to the next level, actually helped them understand the concepts better;
 - whether self-tests helped them gauge their own progress realistically;
 - whether this approach improved their self-confidence.
2. The second part will focus on the impact of web-based tutorials on student learning. Each tutorial will consist of several units and each unit will have specific goals. Assessment tools will be designed to evaluate whether each of these goals is achieved and to what degree. Questions will be designed to investigate how much the tutorials help in enhancing understanding of concepts and acquisition of specific skills.

3. Finally, the value of having the tutorials as a part of the General Chemistry curriculum will be investigated. Student performance from previous years will be compared to that after implementation of these tutorials, particularly in areas covered by the tutorials. Sections of General Chemistry not adopting the tutorials may also be used as controls.

IX. Dissemination

After implementation and assessment during the academic year 2003 - 2004, the tutorials will be made available to any interested faculty member at Southwestern as well as those at all ACS institutions. The tutorials that we envision offer considerable flexibility. They require neither a specific text nor that they be adopted in their entirety. We hope to make the adoption of a complete as well as part of a tutorial simple.

For broader dissemination, we also hope to prepare a manuscript for publication describing the tutorials, their utility in the General Chemistry curriculum, their strengths and weaknesses and the assessments results. A couple of appropriate venues for publication of this work are the Journal of Chemical Education and the Chemical Educator.