

# Development of Computer-Based Activities for Peer-Led Team Learning in University-Level General Chemistry

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**Abstract**—Hybrid print and computer based study materials have been developed as supplements to the “Peer-Led Team Learning General Chemistry” workbook (Gosser, Strozak, Cracolice – Prentice Hall, 2000). These have been used in the General Chemistry course at Coastal Carolina University. Their effectiveness in the PLTL setting has been assessed. Students’ self-assessment of process skill level and an objective evaluation of overall student performance level showed improvement.

**Index Terms**—Computer Aided Instruction, Educational Technology, Chemistry, Collaborative Work.

## I. INTRODUCTION

The development of Peer-Led Team Learning (PLTL) in General Chemistry also known as “Workshop Chemistry” over the past decade has redefined how college introductory chemistry is taught for roughly 10,000 students nationwide [1]. However, the media through which chemistry content is presented has been confined to print-based materials, ignoring the opportunity for introduction of useful electronic materials and development of a wider range of process skills related to computer usage. The focus of our project has been to develop materials and methods that take advantage of the rich pedagogy of the PLTL model to support chemistry students in use of electronic materials or “learning resources” such as interactive applets, computational programs, spreadsheets, digital video, etc. in their learning of chemistry. The variety and scope of resources that are being made available worldwide through the US National Science, Technology, Engineering, Mathematics and Education Digital Library (NSDL) offer an invaluable store of materials that need to be made more accessible to students through an organized and effective pedagogical approach.

Our project has had three objectives that build on the strengths of PLTL and computer aided instruction: 1) to integrate electronic materials that are already available with a comprehensive pedagogical design that fosters student use and

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benefit. This more comprehensive format will be termed “learning objects”. to create learning objects and adapt existing learning resources for use within the context of the Workshop Chemistry pedagogy. 3) to create a reliable curriculum-design process that other instructors can use, and identify features essential to their successful implementation.

Supplemental “e-Workshop problems” were prepared for the weekly sessions and in this pilot study made use of several learning resources. These included simulations in William Vining’s *Chemland 6* program which is available as a free downloadable program running under Windows [2]. They also were prepared for commercially available computational modeling program, *PC Spartan Pro* (Wavefunction, Inc. [3]). Integral to some of these activities were exercises in data manipulation and graphics using spreadsheets specially written for this project in Microsoft *Excel*®. All of the activities were presented as hyperlinked documents created in Microsoft *Word*®. The latter two Microsoft programs were used to generate read-only files that the students could modify temporarily during workshop and then print, but not permanently change. These popular programs were used for two reasons. First, their wide availability and use allows development with minimal technical barriers. Second, the use of these programs by students facilitates their learning of these software packages in the supportive environment of the workshop. Supplementary screen-capture videos were prepared with the instructor’s voice-over using the *Snag-it*® program to demonstrate the use of the software at key points.

## II. DESIGN AND PREPARATION OF MATERIALS

### A. The PLTL Model

The Peer-Led Team Learning Model has been developed and disseminated through support of the National Science Foundation over the past 10 years. Originating as the “Workshop Chemistry” model by David Gosser at the City College of New York, it now involves 160 college science faculty in chemistry, biology, physics and mathematics in 50 colleges and universities in the United States [4].

The essence of PLTL pedagogy is creating well-organized and supportive study groups led by specially trained undergraduate students competent in both chemistry and group facilitation [5]. The instructors of the individual courses carefully design materials for group learning of course content

in weekly two-hour meetings of the PLTL workshops. This model has been studied, documented and refined and is now well established as an effective learning strategy. The critical components for success of the workshop model identified by the PLTL review process clearly outline how omissions of the six "critical components" of this collaborative learning structure can lead to non-productive learning environments or a lack of student interest or sustainability [6]. Although exemplary print-based materials are commercially available, one of the major goals for the PLTL workshop project is to lead adopters to generate original print-based materials for their own students to provide tailor-made instruction through the workshop pedagogy. Most PLTL adopters eventually create at least a part of their own materials as they adopt the model.

Concurrent with the development of the PLTL model has been enormous growth in the scope, availability and use of electronic materials (here termed "learning resources") that consist of interactive computer programs and web sites [7]. These have reached a high level of sophistication with applets for visualization of molecular processes and complex experimental techniques. Often, however, the time and technical expertise required in preparing these resources limits their use and the potential for individual instructor adaptation and implementation. Moreover, many of the applets now available are developed without particular assignments or pedagogy in mind and are left as under-used curiosities accessible by only a few students [8].

The project described here begins to build on the strengths of these two movements. 1) It has integrated electronic materials that are already available with a comprehensive pedagogical design that fosters student use and benefit. This more comprehensive format is termed "learning objects". 2) It has created learning objects and adapted existing learning resources for use within the context of the Workshop Chemistry pedagogy. 3) The process of creating these model learning objects is being documented and refined with plans for dissemination as a model or template. We anticipate that this will encourage other instructors to create effective learning objects using locally available resources.

### B. Curriculum Design Features of PLTL and Learning Objects

The creation of text-based Workshop Chemistry materials has been described [9] and emphasizes the need for them to be appropriately challenging, integrated with other course components and designed to engage the students with both the material and with each other. The first two criteria suggest that the materials are best written by the instructor in the course due to the variations in the level of instruction and the content of individual courses.

The published materials for General Chemistry [10] include a synopsis of the material that will be the focus of the workshop for each weekly meeting to aid students in preparing for the group meeting, and these also contribute to more general adoptability since they are somewhat self-contained and can be independent of the textbook choice and instruction

methods to an extent. These materials also encourage students to study ahead of the workshop by supplying "self-tests" that are completed prior to the meeting. The problems for the workshop meeting itself are traditional in many ways and span a range of levels of understanding and competence. However, the inclusion of other problem types enriches the group learning possibilities. There are multi-faceted problems that the workshop groups approach separately in smaller groups and then complete and assess together; there are also problems that involve use of manipulatives to assist visualization of molecular processes and structures. Conceptual, open-ended problems are also used in the published materials. Some individually devised workshop materials emphasize structured collaborative learning groups with specific assigned student roles. Others emphasize peer-assessment and self-assessment and reflective learning, depending upon the specific desires of the instructor [11].

The creation of the supplemental electronic workshop problems relied upon the rich context of the available published workshop workbook. These supplemental problems are not freestanding, but emphasize particular points and skills that correspond to the existing materials. In the design of them, however, particular emphasis was given to the rationale for the particular assignments in terms of the skill or process being developed by this medium. Many of these exercises require sub-groups to analyze different sets of experimental conditions and then to compare results across the group. Others emphasize spreadsheet and graphical analysis of data collected through an interactive applet. The wide range of our

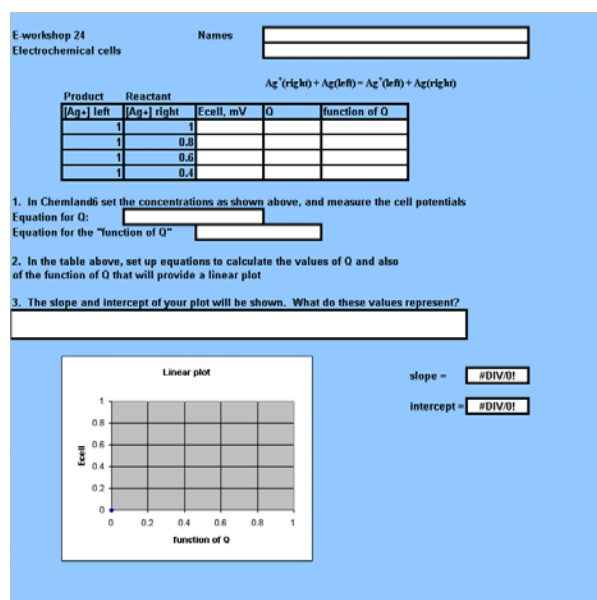


Figure 1. Interactive Excel® spreadsheet for student evaluation of the electrochemical cell in Figure 2.

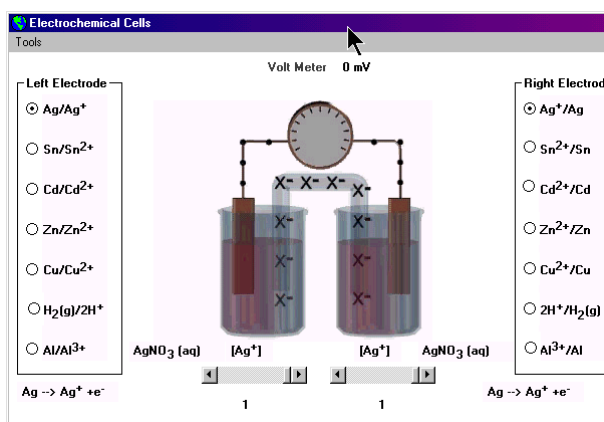
students' experiences with common software tools at the introductory level has prompted us to require their use in the supportive workshop setting, where peers and student leaders can assist in the necessary skill development.

### C. Implementation and Assessment Method

Initial testing of these materials in the spring of 2002 was facilitated by the acquisition of four laptop computers that permit pairs of students shared access to each in the workshop setting. A dedicated conference room is used at CCU for the individual workshops. Its furnishings – a conference table, office chairs, a sofa, small desks, a large whiteboard, small hand-held marker boards, molecular models, etc. – and electronic resources including wireless internet and a laser printer contribute to the socialized learning environment.

The laptops were loaded with Microsoft *Office*®, and *PC Spartan Pro* plus a variety of browsers with suitable plug-ins for use chemistry and animations. The electronic workshop materials were loaded on a CD-R disk used in a standard CD ROM drive. A representative spreadsheet problem and its associated resource, an applet from *Chemland 6*, are reproduced in Figures 1 and 2.

In using these materials, students worked through the traditional problems in the PLTL workbook and replaced selected problems with the electronic activities. The completed electronic workshop pages were printed and turned in for grading with the workbook. Pre- and post-testing was carried out using the CCU *WebCT*® site. Students took these quizzes on-line before and after the workshop meeting if they wished, or using the workshop room's laptops. These pre-and post-workshop quizzes included, in addition to



**Figure 2.** Screen capture of the electrochemical cells applet in *Chemland 6*, used with the interactive spreadsheet in Figure 1.

standard questions about definitions, concepts and calculations other questions that addressed the students' assessment of their process skills necessary for understanding chemistry that were supported by the computer exercises. Representative pre- and post-workshop questions are listed in Table I, with the associated statistics of the anonymous responses. No points were assigned to these pre- and posttest questions since they were not related to the assigned readings or regular workshop problems. The first three deal with the students' perceptions of their skill level on a five-point Likert scale. Neutral responses are not included in the calculation of percentages of agreeing and disagreeing students. The last

TABLE I  
PRE AND POST WORKSHOP ASSESSMENT

Topic/Skill	Agree	Disagree
<u>Student Self-assessment</u>		
(1) Molecular visualization is easy <sup>a</sup>		
Pre-	29%	39%
Post-	43%	12.2%
(2) Graphing visualization is easy <sup>b</sup>		
Pre-	45%	29%
Post-	55%	25%
(3) Spreadsheet equations are easy <sup>c</sup>		
Pre-	41%	29%
Post-	31%	27%
<u>Student Assessment by Instructor</u>		
(4) Interpreting a graph <sup>d</sup>		
Pre-	70%	30%
Post-	88%	12%
(5) Meaning and use of logarithmic scales <sup>e</sup>		
Pre-	51%	49%
Post-	64%	36%

*Complete questions (and answers).*

a It is easy for me to visualize molecules and their interactions in my mind.

b It is easy for me to visualize plots of numerical relationships like concentrations vs. time in my mind.

c I can enter mathematical equations into a spreadsheet and get the correct calculated results.

d Consider the titration curve (pictured and described). In the curve shown, what does the graph show at the volume of 50 mL? (the pH increases dramatically as the endpoint volume is reached)

e In plotting a very wide range of numbers that span several orders of magnitude, a practical approach is (to use a logarithmic scale).

two questions deal with interpretation of a simple graph and the use of logarithms. Percentages of correct and incorrect responses are shown.

### C. Assessment Results

Table 1 lists responses from five of the representative pre- and post-workshop assessment questions related to skills emphasized in the supplemental electronic problems. The text-based questions in the workshop did not deal with these skills. The exact wording of the questions and the number of students responding (n) are given in the footnote of the table.

Comparison of pre- and post testing results shows an increase in students' self assessment of their ability to visualize molecular structures and interactions and to visualize algebraic relationships and graphs of simple functions. The 48% relative increase the percentage of agreement for statement 1 and the 22% relative increase in the percentage of agreement for statement 2 indicate an increased confidence in these skills during the workshop exercises. The 24% decrease in the agreement for statement 3 suggests that students entered with a reasonably high confidence in their ability to use

spreadsheet equations effectively, but left with lower confidence after the workshop. This may be due to the level of challenge in these workshop spreadsheets being greater than their previous experiences.

Questions 4 and 5 were intended to measure actual student abilities pre- and post- workshop rather than student self-assessment of ability. The relatively low pre-workshop scores and the modest improvement during workshop suggest that the essential mathematical skills that are often assumed of students at this level are indeed inadequate for building chemistry concepts upon them. The demonstrated need for continued process skill development at every opportunity warrants continued development of this type of enrichment activity. Our studies of course component choice and student learning styles also suggest that these electronic materials will fulfill a learning need for many students. [12], [13]

### III. PROSPECTS FOR CONTINUED DEVELOPMENT OF ELECTRONIC PLTL MATERIALS

In the development and testing of these computer-based materials in the Workshop Chemistry/PLTL setting, our emphasis upon process skills of mathematics, basic computational skills and visualization that are needed in general chemistry illustrated poor student self-assessment at the outset and somewhat improved performance after a short interactive assignment. The opportunity for continued development of these necessary skills within the framework of the chemistry workshops by itself would motivate continued development. Any pedagogical method that is used for assignments is more effective if students know that course evaluation will be related to the assessments that they receive during the class. As electronic media and web-based testing become more viable options for routine evaluation in the classroom setting, construction of examinations that use these interactive process-oriented questions will be necessary for continued effective use since evaluation methods need to match teaching methods.

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