

## Preparing High School and Freshmen-Level Chemistry Teachers for Teaching and Learning in an Activity-Based Framework

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### ABSTRACT

Our paper describes the fundamentals of and experiences from a series of workshops on activity-based teaching and learning that have been presented in Latin America and the USA. The approach is research-based scientific teaching through experimentation by learners, rather than only traditional class lectures. The content framework is built on the core concepts upon which chemistry is founded. The emphasis is on three levels of description of phenomena:

laboratory (observable behavior of matter)

molecular (atomic/molecular interpretation of the observations)

symbolic (translation of molecular understanding to the symbolic language of chemistry)

The workshop methodology, which parallels what we expect will be incorporated into participating teachers' classrooms, includes:

introducing a concept by a short experiment designed to be carried out in small groups.

discussion among students (participants) and teacher (presenter) of the observations and development of molecular-level hypotheses/interpretations.

using guided-reasoning exercises/worksheets to structure interpretations and problem solving.

encouraging students to apply their understanding to other situations.

Changing teachers' minds about learning is a crucial step in the process of getting them to use these methods in their own teaching.

### BACKGROUND

Research on teaching and learning over the past several decades has provided a better understanding of how students learn and the teaching methods that are most effective in supporting student learning in the sciences. "There is mounting evidence that supplementing or replacing lectures with active learning strategies and engaging students in discovery and scientific process improves learning and knowledge retention" *Science*, 2004, 304, 521-2. Teachers at all levels need to become aware of these results and learn how to incorporate new strategies in their classrooms and laboratories, in order that all students will learn the science and more be attracted to scientific careers. An effective way to help teachers at all levels adopt new methods is for them to participate in workshops that use these active learning strategies to help participants learn about the strategies as they are engaged in them. This is the workshop model that has been used with secondary and tertiary-level teachers in the United States, Mexico, Guatemala, and Panama.

To support and reinforce chemistry teachers who want to incorporate activity-based learning and more student engagement in their classrooms, the American Chemical Society (ACS) produced a general chemistry textbook, *Chemistry*, that incorporates this pedagogy. The textbook has been translated into Spanish and the availability of *Química* is the bridge between the ACS and teacher workshops in Latin America. ACS, through its Committee on International Activities and the Office of International Activities, has collaborated in Latin America for decades. We work with sister chemical societies, national science and technology agencies and institutions of higher education to develop and sustain linkage programs. The ACS is a recognized civil society organization with the Organization of Americas States, and in response to the OAS Lima Declaration has focused on helping to improve science education in the region. The ACS *Química* workshops are an extension of this engagement.

While the activity-based pedagogy of the workshops can be used with any text, we use the ACS textbook as the content base for our workshops, so that all the pedagogy is embedded in a context of science content. Concepts covered in the ACS *Química* workshops are introduced by short experimental investigations carried out in small groups as participants work to

develop concepts based on the results of their investigations, most of which are included in the textbook. The activities are designed to be done in the classroom as a way to get discussion started as concepts are developed. Discussion within the groups, between groups, and with the workshop leaders is an essential part of the workshop design as participants learn from their peers and experience how their students should also be encouraged to learn from one another. From these discussions, often using guided-reasoning exercises/worksheets, participants are encouraged to develop molecular-level interpretations or hypotheses. We try always to move first from the concrete observable phenomena of the investigations to molecular-level, usually pictorial, explanations/interpretations of the phenomena. Only after participants agree upon and are comfortable with these explanations do we proceed to the symbolic representations that are the traditional language of chemistry, but which students too often do not connect to the molecular world.

Several of the workshop activities are open-ended, so that participants have to design their own methods for solving an experimental problem in order to gain experience developing such activities for their students to carry out and interpret. Sharing these methods and the outlines of activities the teachers propose to use in their own classrooms enriches the workshops and helps to embed the methods in the culture of local schools. Workshop participants enjoy this approach, see that their students probably will as well, and are prepared to try the strategies in their teaching.

The lead presenter at the initiation of workshops in each Latin American country has been the chief editor of the textbook, Jerry Bell. Ideally we would like this to be at least a five-day, activity-based chemistry education workshop with the expectation that up to 32 higher education and secondary level master teachers representing key areas of the country will be the participants. While presented orally in English, workshop content and materials have been translated into Spanish, and bilingual participants and/or collaborating partner faculty are identified in advance and assist in communicating and localizing content as well. We anticipate that workshop participants will return to their home institutions to practice the techniques in their own classrooms. If necessary, additional follow-on training can be provided during a national chemistry or chemical education congress, for example. The focus is to enable workshop participants to provide training to their colleague instructors nationwide on the concepts and practices of this pedagogy. The intent of the ACS participation in this activity is to help develop local expertise and leadership to carry on without a direct ACS presence.

For our workshops in Mexico, Guatemala, and Panama the local organizers were able to secure funding from the ministries of education and science and technology to cover the local expenses including materials. Materials for the workshop include a copy of Química for each participant (available through Editorial Reverté publishers) and a Molecular Structure Model Kit (available from W. H. Freeman). Freeman has provided each participant with the faculty CD that accompanies the English language textbook. As part of its contribution to the workshops, ACS has covered the presenters' airfare to/from the countries for the workshops. Room/board and incountry transportation are covered by the local organizers. To provide specificity to the broad outline sketched above, the next section relates the history and results from these workshops in Mexico and the partnerships that made them both possible and sustainable. The final section of the paper is a brief summary of the programs in Guatemala and Panama.

## Implementation in Mexico

In January 2006 a partnership among ACS, Editorial Reverté publishers and the National Autonomous University of Mexico (UNAM) School of Chemistry was initiated to organize and deliver activity-based chemistry education workshops to college professors as well as high school teachers in Mexico. Dr. Jerry Bell has participated whenever it has been possible and Professors Graciela Müller and Mercedes Llano have been leading the experimental work that has taken place in every case.

The first 20-hour workshop was presented to 25 professors in the UNAM Chemistry Faculty. The participating teachers, all of them specialists in their subjects, represented several academic areas of the faculty (General Chemistry, Inorganic Chemistry, Nuclear Chemistry, Organic Chemistry, Physical Chemistry and Analytical Chemistry). All also teach in the UNAM-General Chemistry Course taken by all freshmen students and the focus was on issues and experiences related to instruction in general chemistry. Dr. Bell began the workshop with two days of participant activities, Figure 1, illustrating the activity-based, learner-oriented pedagogy of the textbook.



Over the next three days, Drs. Muller and Llano led the activities and discussion as participants gathered in cross-disciplinary groups of five to six professors to work through more activity-based exercises and experience them as would their freshman-level general chemistry students. Participants were asked to propose how they would present their topics to freshmen students. Participant evaluations of this short-form workshop suggested that the workshop and text content, while valuable, were not calibrated to the current programs and expectations of the general chemistry course at the UNAM School of Chemistry where instructor and student typically do not have previous knowledge and experience with activity-based pedagogy and where the content progression of the textbook does not parallel the course structure. Thus, it was suggested that a more meaningful and appropriate platform to pilot and promote the pedagogy in Mexico would be chemistry at the secondary level.

In March 2006, Drs. Muller and Llano presented a 30-minute lecture on activity-based chemistry education at the 5th Meeting of Junior High School and High School Teachers of Chemistry to an audience of more than 50 teachers. Feedback from this presentation suggested that the text could readily fit at the high school level owing to the fact that the content, explanations and pedagogy are adaptable to the current official programs.

A third presentation was given in September 2006 at the 25th Congress of Chemical Education organized by the Mexican Chemical Society (SQM) in Mexico City. This was a three-hour workshop offered to 60 instructors from secondary and tertiary-level public and private institutions throughout Mexico. Dr. Bell opened the workshop providing contextual remarks on activity-based chemistry education and incorporating some activities. Drs. Muller and Llano then led the substantive activity-based content for the greater part of the session. The participants were grouped in five different teams to work together on activities from the textbook and some others common to secondary classrooms, Figure 2. These included:

- Characteristics of solutions of ionic compounds in water
- Energy changes when ionic compounds dissolve
- Solubility rules for ionic compounds
- Precipitation reactions of ions in solution
- Continuous variations and stoichiometry
- Energy and bond enthalpies
- Solutions of gases in water
- Periodicity and the periodic table

When the activities were completed, the groups prepared transparencies and, through an appointed spokesperson, presented their experimental results and conclusions. They also added their own experiences and comments on the relevance of the pedagogy to their instructional settings. This sharing and discussion provided each participant some familiarity with all the activities presented.

**Figure 2.** Drs. Muller and Llano leading activities, SQM Congress workshop, September 2006.



As a result of this last workshop, there have been many applications from different public and private high schools for workshops in which their chemistry professors can receive the necessary tutoring to adapt the ACS project in their chemistry courses. Drs. Muller and Llano are working with the publisher of Química, Editorial Reverté, and college preparatory high school chemistry faculties to organize and deliver activity-based chemistry workshops throughout Mexico City and nationwide. For example, the publisher has helped to arrange a December workshop for the chemistry faculty of LaSalle University, Figure 3, one of the largest private universities in Mexico. The SQM's 2007 annual congress will be held in Guadalajara, and organizers for the event have expressed interest in possibly offering a longer pre-congress workshop to share the form, content and best practices from these workshops with a wider audience in Mexico. Beyond the workshops, a favorable review of the Química text appears in the October-December 2006 issue of Educación Química, 2006, 17[4], 114-119.

**Figure 3.** Participants at the LaSalle University workshop testing magnetic properties of oxygen.



The example of Mexico can serve as one model for the adoption and diffusion of activity-based pedagogy in chemical education. A shortcoming and limitation of the Mexican implementation experience has been the lack of sufficient hours to train teachers in the optimal use of the textbook. A Spanish web page specifically designed for permanent tutoring is a possibility be considered as a convenient support for those teachers who choose to use this textbook and/or the activity-based approach in their teaching. In going forward, the 2009 ACS Southeastern Regional Meeting (SERMACS) will be held in Puerto Rico and will convene chemical scientists from throughout the region. This meeting could provide an attractive and convenient site, serve as a catalyst to build broader interest in active-learning methods in Latin America, and present an opportunity for Mexico to take a regional leadership role in providing workshops there.

### Programs in Guatemala and Panama

Drs. Bell and Miller teamed with university hosts to present one-week activity-based learning workshops in Guatemala in June 2006 at the Universidad de Valle de Guatemala for 32 participants and in Panama in July 2006 at the University of Panama for 21 participants. Organizers of the Guatemala workshop have created a listserv to continue interactions among the participants and are exploring provision of another workshop in 2007. In Panama, the Ministry of Education has requested that the University of Panama develop teacher professional development workshops for all the basic sciences and the Dean, who has been very supportive, has designated the workshop we gave in July as the model that chemistry should use. We have been invited to return to Panama to do two one-week workshops in February 2007, one in Panama City at the main campus and another at a provincial campus in Santiago. Each of these workshops will accommodate 30 participants, several of whom will be university faculty charged with carrying out similar activity-based workshops for secondary teachers during the summer of 2007. The goal is to have reached about 80% of Panama's secondary chemistry teachers with this kind of professional development opportunity by the end of 2007. The follow-ups to our initial workshops in Mexico, Guatemala, and Panama very successfully meet the ACS goal to help develop local expertise and leadership to strengthen chemical education in these countries.

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