Changing the Education System With CALM: COMPUTER ASSISTED LEARNING METHOD

A Web-based learning tool that gives students practice in solving chemistry problems was originally intended for use in a university setting. Its adoption in high schools provides a good example of the kind of cross-level cooperation that a P-16 system would make possible.

BY ROMUALDO T. deSOUZA, CHERYL L. McLEAN, AND PAULETTE BERGER

OVER THE past decade, at both the university and high school levels, chemistry instructors have become keenly aware of an increasing number of students who are proving to be unable to solve complex problems. Today’s students have grown up with technology, and most would prefer to do their homework using a digital tool rather than pencil and paper. Those students who do try to work out pencil-and-paper problems can become easily frustrated if they encounter difficulties and are unable to get immediate, useful feedback.

To address this problem, chemistry department faculty members at Indiana University, Bloomington (IUB), developed a novel online learning tool called CALM (Computer Assisted Learning Method). CALM was initially developed for use in the general chemistry curriculum at the university, where introductory courses typically enroll between 200 and 600 students. But CALM has since made the transition to high schools, crossing one of the most formidable boundaries in U.S. education and demonstrating the potential of a P-16 system to fos-

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The story of CALM’s beginnings is instructive. In 1996, the first author decided to introduce online homework into a large undergraduate chemistry course at IUB. The idea behind this change was simple: science involves problem solving, and to master concepts in science requires practice in solving problems and answering questions. The advantage of an online system was clear: it could provide instant feedback to the students on the correctness of their responses. Moreover, an ideal system would challenge students according to their individual strengths, so that all students would be appropriately challenged.

But in the mid-1990s, online homework systems were in their infancy, and none possessed all the desired features. Consequently, it was decided to develop a system from scratch. Because developing high-quality instructional materials is both time- and resource-intensive, from the outset those of us at IUB wanted to create a system that could be broadly disseminated so that materials developed at one institution could benefit students at multiple institutions. The result of our effort is the Web-based learning tool known as CALM (http://calm.indiana.edu).

Early in the development of CALM, the IUB chemistry department decided to share this learning tool, free of charge, with any high school teacher willing to be trained to use it. The training required to start using the program builds important connections between the university faculty and the high school teachers and so is in harmony with the P-16 philosophy. At the same time, high school teachers throughout Indiana have made important connections among themselves. As a result, the use of the program has dramatically increased within the state, and it has yielded some amazing outcomes.

**DESCRIPTION OF CALM**

A faculty member using CALM presents students with a set of questions to answer. These questions can be associated with review material, subject matter recently taught in the classroom, or even untaught material so as to gauge the level and abilities of the class in advance.
The architecture of CALM is based on Socratic pedagogy. When a question in CALM is answered incorrectly, the architecture allows a new leading question to be posed. Thus a student can be led, step by step, through a complex problem requiring multiple steps. Since the student’s responses to this unfolding series of questions can be tracked, common stumbling blocks encountered by multiple students can be brought to the attention of the teacher.

Questions in CALM are generated by an algorithm, and different students in the same class will encounter different though similar questions. This algorithmic generation of individualized questions is a key feature of CALM. Not only may the question differ in numerical values, but chemical reactions or graphical images can change as well. Students working together to solve a problem in CALM must communicate symbolically and understand what the concepts mean. They cannot just “share an answer.”

In effect, each question in CALM is part of a database that allows the algorithm to generate a sensible question for each student from a question template. In this manner, a large number of questions can be generated from a single question template. Since CALM generates a question algorithmically, it also calculates the correct answer, which enables the program to provide students immediate feedback on the correctness of their responses. Students are allowed multiple — in most cases, unlimited — opportunities to solve a problem, and so they are encouraged to spend time with the material.

CALM is perhaps better classified as a “learning tool” than as a “testing tool.” The questions developed in CALM constitute a large keyword-searchable database on a range of topics. Integrated tools make it easy for faculty members to search for and view questions in the database and to assign them to their students.

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Our initial experience with CALM in a second-semester general chemistry course was overwhelmingly positive. Students appreciated being kept on track. The immediate feedback from CALM elicited an interesting response. While in the past students working on a pencil-and-paper assignment would complete the assignment to the best of their abilities and turn it in, with CALM, students who were frustrated by incorrectly solving a problem spent considerably longer working on their assignments. They reported a high level of satisfaction upon correctly solving a problem.

We observed that the CALM experience provided a valuable change in the culture of expectation with regard to chemistry courses on campus. CALM rapidly spread from one undergraduate chemistry course to all first-year chemistry courses. These courses range from remedial courses for those students entering the university ill prepared for the main sequence, to the main sequence of courses required for chemistry and biology majors, to the allied health-science tracks. It is interesting to note that different faculty members employ CALM in different ways, from using it as a voluntary...
review tool to using it as a mandatory part of the course and an integral component of the course grade. In the past couple of years, CALM has also been adopted by the physics department for its introductory courses.

**CALM IN THE HIGH SCHOOLS**

In 2001, it became apparent that a wonderful opportunity to provide CALM to high school teachers was being missed. We were convinced that CALM could aid high school students in learning science, in particular chemistry, as well as serve as a vehicle for networking university faculty members and Indiana high school teachers. Initially, CALM was introduced into AP courses, as the only available questions in the original database were aimed at the first-year university level. Following initial success in these advanced courses, questions appropriate for the first year of high school chemistry were developed by high school teachers, and the use of CALM was expanded to introductory high school courses.

The growth in usage of the program over the past four years has been dramatic. At present, 82 Indiana high school teachers in 54 Indiana high schools are using CALM in locations throughout the state. Thus, in addition to a couple of thousand university students at IUB, more than 1,000 high school students now use CALM each year. Indeed, visitors to the CALM website will see that there are log-in buttons for both “high school” and “college.”

New teachers are introduced to the program through a series of workshops that make use of a master-teacher approach. By involving teachers who currently use CALM, the workshops expose new teachers not only to the nuts and bolts of the program but also to the innovative ways in which teachers adapt CALM to the high school environment.

A common pattern of adoption has emerged over the years. In each high school, teachers typically adopt CALM first for their smaller AP courses and second-year courses. Upon observing the impact on students in these advanced settings, they move to expand its use to the larger first-year courses.

**WHAT TEACHERS SAY ABOUT CALM**

While we are now engaged in assessing the impact of CALM, one telling sign of its success so far has been what teachers using the program have to say about it. In a recent anonymous survey, 73% of teachers rated CALM as “a very good or excellent tool that they would recommend to other teachers.” When asked to discuss the perceived impact of CALM on their students, most said that the immediate feedback and additional practice have provided a deeper understanding of the material. Individual testimonials on teachers’ experiences with CALM have been even more informative.

One particularly exciting aspect of CALM, to judge by teacher responses, is the immediate feedback the system provides. “One of the best things about CALM is instant student feedback,” said one of the survey respondents. Students know immediately if their answer is correct, and, since CALM is a learning tool as opposed to a testing tool, students are allowed to rework the question if their answer is incorrect.

High school chemistry teachers who use the system are excited because the design of CALM forces students to discuss the problem-solving process, not just to share answers. Consequently, students are spending more time on their homework and understanding it better. “I have observed many good discussions on ‘how’ to do a particular problem,” said one teacher. “Students are performing better on assessments.” Said another, “I like CALM for many reasons. But one of the biggest is the discussion it generates in class.”

And our survey results indicate that CALM can help motivate students to work harder on chemistry. “I love the program and my students love it,” said one teacher. “I was amazed to see how responsive and motivated they have become since the program was first introduced to them.” Another noted that students who were once disengaged have connected with their learning through CALM. “I marvel at how seriously the students take CALM assignments,” said the teacher. “I could give them the same assignment on paper, and many of them simply would not do it.”

The Web-based learning tool that we have developed has great promise for altering the learning outcomes for both high school and university students. But just as important, we have developed a model for disseminating it that builds bridges between university faculty members and high school teachers. Both are, after all, engaged in the pursuit of a common goal. For the future, we are now seeking funding to support and further disseminate our work, both within Indiana and nationally, and to conduct a more rigorous evaluation. Moreover, we hope to expand the reach of the CALM model to other subject matters and even to the middle school level.

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