Chemistry goes global in the virtual world

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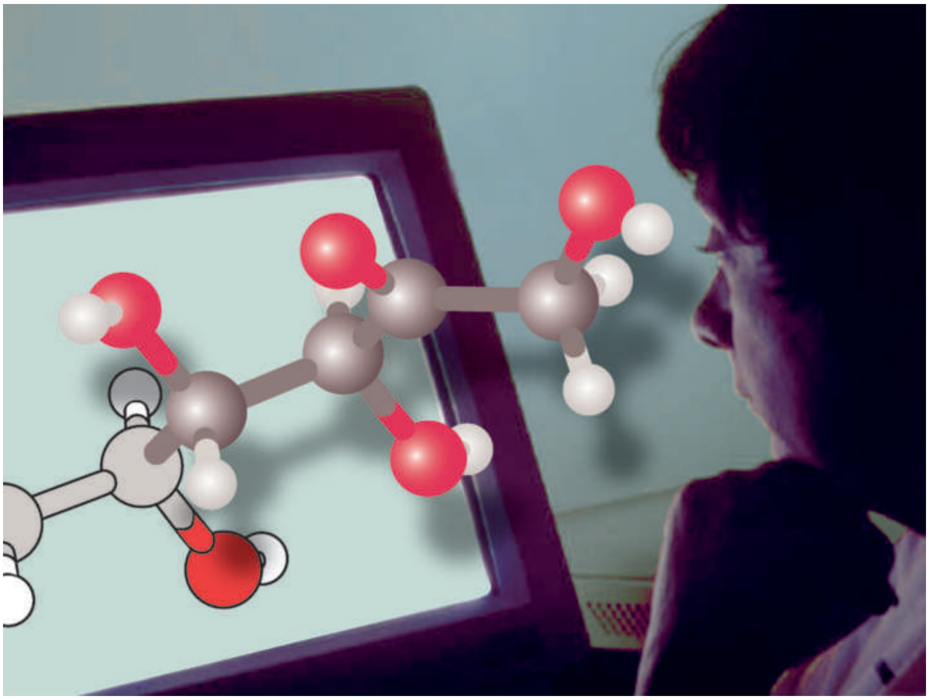
Online courses administered by the University of Illinois at Urbana-Champaign show that it is possible to create an effective network of professors and students from across institutional and national borders all learning together — even in conceptually challenging subjects such as organic chemistry.

The Internet is a force to be reckoned with. Information that used to be confined to library stacks is now available at anyone's fingertips. Anyone anywhere can learn anything — at least in theory. But knowledge is more than information. Are we living in a world that is information obsessed and knowledge deprived? Transforming information to knowledge — especially for pervasive subjects such as organic chemistry — is a challenge for today's information-obese world in general, and chemical educators in particular.

Technology has given us information on demand. Can technology also assist in the large-scale dissemination of the knowledge that this information has to offer? We have begun to address this question by changing the way in which organic chemistry instruction is delivered at the University of Illinois at Urbana-Champaign. Finding a way forward is exciting because it moves the world closer to truly realizing the vision of 'Chemistry for everyone'[1].

As information can be obtained on demand, it is increasingly clear that the traditional lecture has lost the value that it once had[2,3]. What's more, in courses such as organic chemistry, homework can be submitted and checked with immediate guided feedback using tools like ACE Organic — a web-based interface[4]. ACE Organic allows students to draw organic structures in response to questions. ACE then analyses the response and, if it is wrong, ACE provides instantaneous feedback that specifically addresses the error that the student made without giving away the answer. When students receive instant help they tend to correct their mistakes right away; consequently, they are less likely to propagate bad habits.



DOROTHY LOUDERMILK

Online learning offers new opportunities for how subjects such as organic chemistry can be taught and overcomes the limitations of traditional classroom teaching.

The most innovative features of ACE are its abilities to analyse multistep mechanisms, including electron-flow arrows of the usual type, and to provide appropriate feedback depending on the nature of the student's error. These open-ended problems are as sophisticated as any question that an organic chemistry student would encounter on a traditional paper exam. Coupling this with software such as Elluminate Live enables interactive sessions in which problem solving, critical thinking and assimilation of material can be achieved. These online tools make it possible to connect students from various locations on the planet or to see complex three-dimensional structures that cannot be viewed on a chalkboard or a piece of paper[5,6].

To test these tools as a learning medium, we have created a fully online course in second-semester organic chemistry at the University of Illinois at Urbana-Champaign. It is largely based on physical organic chemistry and covers molecular orbital theory, reaction mechanisms and an introduction to bioorganic chemistry using the tools from molecular orbital theory and mechanisms introduced earlier in the course. This online course has been taught twice: first in the summer of 2008 to 37 students and again in the autumn of 2008 to 181 students. There is no face-to-face interaction whatsoever between the students and the instructors.

Despite the lack of face time, the course promotes a high degree of interactivity. Students communicate with one another and the instructors both through a synchronous environment for three hours a week using Elluminate Live and through an asynchronous environment using a discussion board on the course website. As instructors, we have found — quite unexpectedly — that one learns about students' performance capabilities on a personal and individual basis just as effectively as in any other setting in which we have taught.

Course content is delivered entirely online in two different formats. In the summer of 2008, students watched Internet-streamed 50-minute lectures archived from the previous semester using Mediasite, a program for capturing audio and video input synchronously with presentation slides. In the autumn of 2008, students had the option of either viewing the archived lectures or watching shorter segments streamed in the form of webcasts. For the webcasts, content from the traditional 50-minute lecture was used to create five or six segments, each six minutes long and covering a specific topic.

Two advantages of the webcasts are the ease of cataloguing the content and the streamlined presentation. Cutting out one's "ums" and "ers" and eliminating classroom distractions gives a sharp focus and deliberate intent. The webcasts also contain 'Action Items', which include Internet hyperlinks that, with the click of a button, enable the student to learn more about any unfamiliar topic or word. Not only is the boring traditional textbook transformed into animated and hyperlinked content, but its outrageous cost is replaced with immediate and free information. Students are typically sent to verified Wikipedia articles for definitions, and to sites with demos, videos and animations for more complex phenomena. Occasionally, students are intentionally sent to sites with erroneous information and asked "what's wrong here?" This teaches the invaluable skill of information filtering and encourages students to become more critical of technical Internet content.

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Examinations are given synchronously using a combination of ACE Organic and Elluminate Live. Students report to a computer lab on campus or to a local library or community college, and there they receive a copy of the exam on paper. Instead of recording answers on the paper copy of the exam, the answers are put into ACE Organic. The exam questions are carefully drafted from contemporary chemical literature and are designed to test understanding and reasoning abilities. Moreover, the features of ACE Organic mean that the exam questions are not restricted to multiple choice, matching or numerical answers (see Fig. 1 for an example).

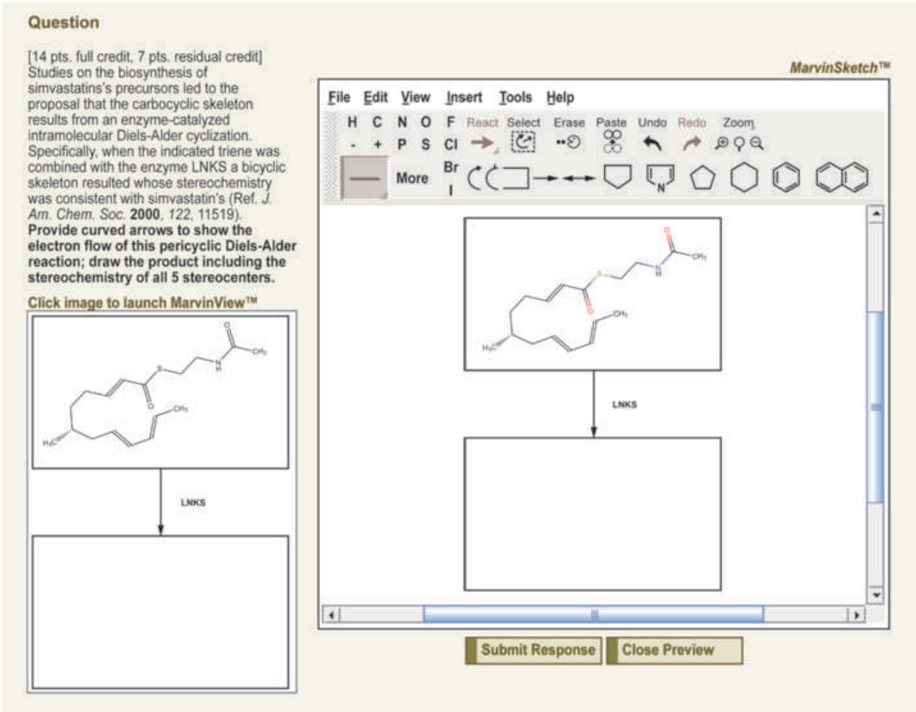

Figure 1 | A screenshot of an exam question used in the online course at the University of Illinois at Urbana-Champaign. It illustrates a very simple use of curved arrow notation and (somewhat more challenging) stereochemistry. A link to the literature is included to show the question's relevance to current chemical research.

The Elluminate Live environment puts security checks in place and forces strict time limits to deter potential cheats. In this environment, students are allowed to roam freely on the Internet and use whatever textbooks or notes they want, with the exception of blogs, Facebook, Twitter, e-mail or any site that allows two-way communication or posting of questions and answers. This policy of "anything but a friend; non-friends also apply" tests students under conditions typical to the practising research chemist. Chemists peruse textbooks, primary literature and Internet sites to find information and use computational tools to help solve a given problem — why should our students undergo an examination procedure any differently?

Another unique aspect of the examination is the grading. As the exams use ACE Organic, the answers are checked instantly, and students are immediately informed whether their response is correct or incorrect. Students then have the option to submit a different response in an attempt to gain points, continuing as many times as they'd like until they successfully solve the problem or exam-time has expired. For each problem, students receive points only if they find an acceptable solution, and they are scored according to how many attempts it takes them. This grading style is closer to real-world problem solving than traditional 'partial credit' because students can attempt to solve the problem more than once. It provides immediate corrective feedback, which reinforces learning and the acquisition of knowledge.

The intent of an exam problem is to probe whether a student has the ability to solve it, and the new grading system does just that. The traditional 'partial credit' grading system enabled students to answer a question just once, and the grader assigned arbitrary point values according to how close the student's response matched the correct answer. The 'partial credit' system was the best that instructors could do with paper exams because students' knowledge could only be probed once. In the online format, students must diagnose incorrect responses and find solutions, just as any research scientist would do in the laboratory.

Another advantage to the online exam format is that instructors are free from the labour-intensive, mistake-ridden practice of old-fashioned hand grading. Moreover, students can be required to retake exams if performance does not meet expectation. Post-exam learning, motivated by offering a fraction of the original credit and the freedom to work collaboratively, has been a huge and unexpected instructional bonus afforded by machine-graded exams. This approach reinforces the learning and application of current fundamental concepts.

These advancements have made it possible to teach a highly interactive online organic chemistry course to a class size of up to 200, and in spring 2009 the course is being taught with an enrolment of 350 students. Detailed assessment of the course is underway and the findings will be forthcoming. Our preliminary conclusion is that in terms of learning outcomes and student satisfaction, the trial offerings have been successful. The pilot run in summer 2008 had students spread throughout the state of Illinois, but there's no reason to limit the geographical boundaries. Anywhere there is an Internet connection, students can log-on to learn and get help. Discussion sessions have been moderated from hotel lobbies and airport terminals thousands of miles away without missing a beat.

Now that course enrolment is no longer restricted to the size of the lecture hall, why stop at 350 students?[7] As the content is not special to any one location or professor, it is possible to create a network of professors and students across institutional and national borders all learning together. Transforming colleges and universities from a 'pay-for-teaching' to a 'pay-for-accreditation' model would facilitate global, megastudent classrooms. Interested learners from all walks of life around the world could get interactive help on demand. We conducted a preliminary experiment of this sort during the autumn 2008 semester. Students of Professor Dahui Zhao of Peking University in Beijing, China, regularly logged on to our discussion sessions along with students at the University of Illinois at Urbana-Champaign. The students at both universities were able to connect with one another in real time, and they drew reaction mechanisms for all to see.

As more experts across the globe join in, students will have access to professional chemistry help 24 hours a day, 7 days a week. Anyone who has a question can log-in to 'organic chemistry customer service' and have their questions answered by a trained professional[8]. That's not just information on demand, but knowledge on demand. ❐

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