Developing and Using Information Technologies to Teach Chemistry

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Developing and Using Information Technologies to Teach Chemistry

Nick Turro  
William P. Schweitzer Professor of Chemistry  
Columbia University  
turro@chem.columbia.edu

Why use technology?
My interest in technology arose about the same time as my interest in the way that students learn. This occurred in the ‘80s when I was teaching general chemistry. I had 40 students -- out of a class of 250 -- who were failing the course and I just couldn't seem to reach them. I was trying everything and nothing seemed to work.

So, some colleagues and I performed two experiments. The first experiment helped us to understand the learning process of these struggling students and the second demonstrated that technology could actually help students to learn. These two experiments led to the creation of a piece of software on spectroscopy, called IR Tutor, which introduced students to underlying concepts of spectroscopy and enabled them to interpret spectra within minutes.

We were very happy with the result of IR Tutor and thought, “Everyone could use something like this in their course!” Creating technologies that explore a topic and enhance learning seemed exciting, and we thought that other Columbia faculty would like it too. So, what I want to tell you about is both how we developed those resources, and how I currently use them in my teaching.

Strategies for developing new resources
An experiment on student learning

To help me solve my problem with the 40 students who were failing, I contacted a professor in science education at Teacher College of Columbia University. She helped me to organize "help" sessions at which the students would actively learn and at which we -- the instructors -- would observe.

In these sessions, students worked in teams to solve chemistry questions. We listened as they worked through the problems and realized that they thought of chemistry in a very different way than we were teaching it. For example, in solving problems we found that many of them had difficulty in determining how to select between rules when one of two or more rules could apply. They understood the individual rules and how to apply them. The problem was finding criteria to decide which was the more appropriate rule for a given situation. This was a revelation for us because we had been assuming that they were getting the answers incorrect because they didn't understand the rules. In a number of cases the students did not realize that there was a decision to be made. They remembered a rule and applied it immediately without realizing there were others that could also apply. This finding allows us to emphasize the process of rule selection to this group of students and to students in general.

In addition to the learning about the difficulties these students faced in selecting the appropriate rules to solve problems, we also learned that students benefited from interactive engagement
with peers in working on problems that were put into context by the instructors, and that they performed better when they were able to visualize the chemistry. Of course, more structured research on teaching and learning during the last two decade has shown that our results were typical.

We found these "help" sessions to be very effective: the 20 students who participated in these sessions earned, on average, a B- on the remainder of the course! Those students who didn't participate in the sessions basically failed the course. However, we only offered these help sessions the first semester, and sadly, the 20 students who showed such improvement in the first semester fell into the failing pathway their second semester of chemistry.

This little experiment told me that teaching and learning was complex and required sustained effort. This started me on a path to teaching differently.

An experiment to test how technology can support learning
While I was learning about ways to improve my teaching, computers were just starting to be used to visualize chemistry. Again, this was the '80s, and the software and computers were too klutzy to really be useful in classroom situation and delivery systems in large lectures were not available. But we kept an eye on new developments and were rewarded with a program called Macromind Director that enabled us to create customized multimedia presentations.

We explored Marcomind and discovered that we could do some nifty things in terms of visualizing Chemistry with it, but questions remained: How useful were visualizations going to be with respect to student learning? Did we have to hire a programmer to produce the modules? Could we find ways to make something useful that was also cost effective?

So we did another experiment. We hired a graduate student named Charles Abrams to create a module on infrared spectroscopy using Macromind Director. Since there was no funding available for producing IT modules at the time, we convinced the Perkin Elmer Corporation, which makes infrared spectrometers, to support Charles. We grounded this software in what we knew would help students learn: we made it interactive to increase their engagement with the material; we used a lot of visualizations to give students a variety of ways to understand the data and help visual learners; and we tried to put to material into broad contexts of chemistry.

The resulting piece of software was IR Tutor. This turned out to be a great program, especially for giving people introductory information on IR. In fact, I got my brother-in-law who knows no chemistry to use it, and in 20 minutes he was interpreting an IR spectra.

Increasing our campus colleagues’ use of undergraduates and of technology
As I said above, we thought our colleagues would appreciate help in using technologies for teaching, and -- in the process -- may even start thinking differently about how they teach and how students learn.

Now, the issue arose as to who would actually produce modules for faculty? We knew that creating modules wouldn't be appealing to your typical graduate students, who would be occupied with their own research. But what about undergraduates? We had many who were excited about working directly with faculty and willing to perform work for relatively little compensation. However, we weren't sure if they could do anything useful. If they could, then we would have a win-win situation: the undergraduates would benefit from their interactions with faculty and science, and the faculty would get some useful technology out of the deal.
To find out if undergraduates were an answer to the problem of producing IT modules for faculty, we needed to perform another experiment. In order to fund the experiment, we applied to NSF and received $60,000: $2,000 for 15 students to work over the summers of 1995 and 1996 developing software under the direction of a professor who had some need or interest. We selected students who had good interpersonal skills, were eager and who had taken at least one year of college chemistry, but who were not necessarily skilled in computing.

We developed a workshop, supervised by a postdoctoral associate whom I funded, to train the students how to use the modules for developing visualization for chemical principles. And, students in the workshops with more experience with computers helped those with less experience. During that training, we matched each student with a professor and left the two alone. This matchmaking worked 70% of the time and when it worked, it worked well. Students were producing high quality software for visualizing chemistry that were being used in the undergraduate courses.

After two years we were convinced that the undergraduate model worked, so we went to the university and said, "Look, we've got an idea here about helping faculty to get involved with information technology and the web." The university administration was interested in producing means to educate faculty in the use of IT for teaching and learning and was enthusiastic about our efforts.

The university agreed to support students to work with faculty to use IT for educational purposes for three years. The plan was to start with faculty from the science and engineering departments because they were most savvy about computers and had an inherent interest in IT from their research programs. Then we planned to incorporate faculty from the humanities and the social sciences in the second year, and then in the third year, to work with the university to set up a permanent center that would take over the training of faculty in the use of IT for teaching and learning. Indeed, by the end of the third year, the university created the New Media Center for Teaching and Learning, a center that supports faculty in the use of technology in the classroom.

**Support for creating the IT**

The initial support to develop IR Tutor came from the Perkin Elmer Corporation and the support for the undergraduates came from the NSF. From that point on we were able to use university support to purchase software and hardware that were needed to produce the IT modules and to demonstrate them in classroom with projectors that could be moved around on "smart carts." The university built us an electronic classroom: we no longer had to bring the technology on a cart, it was built into the room. The level of demand and support kept building up and now we're at a level where it is reasonable to do demonstrations using technology in most classrooms.

**IR Tutor**

The first module we developed, IR Tutor, provides an introduction to spectroscopy and enables students to interpret spectra. The software demonstrates, through animated graphics, the normal vibrational modes of molecular vibration, such as stretching, bending, and rocking.

You can download a demo, for Mac or PC, from the IR Tutor website and can purchase the software from Wiley Publishers by contacting them at science@wiley.com. IR Tutor is available for use on either a Macintosh or PC.
IR Tutor can be used across the curriculum. I can use it in general chemistry, organic chemistry, physical chemistry, and graduate courses. It is such a great program, especially for giving people introductory information on IR.

How I use these resources in my current course
You may recall that the first piece of software, IR Tutor, was conceived for a general chemistry course; however, I no longer teach that course. The course I currently teach is Intensive Organic Chemistry For Freshmen (Chem C3045). This 40-student course is for freshman only, requires a special placement exam, and is taken mainly by chemistry majors or other sciences.

I use various kinds of technology in the course. I have a web page which contains the syllabus, question of the week, and discussion board. All of the chapters in the text are linked to a computer slide show review of the chapters that students may download over the web. I use IR Tutor, ChemDraw, Organic Reaction Mechanisms, ChemTV, Spectra Deck, Spartan, and other software modules that help the students to understand molecular structures.

In my years of using technology in the classroom, I've determined three critical conditions for it to be successful.

- Students need to understand why technology is being used. If they don't know why, they'll see it as extra work since technology is not used in many classes. In my current class, I explained to them on the first day why I was doing this stuff; they began hemming and hawing, but from comments on the course evaluation at the end of the term they clearly learned to appreciate IT modules as tools for learning chemistry.
- The software has to be practical and available. I rarely use e-mail to distribute homework or handouts because students have such different email systems and software configurations that it ends up being more work to solve their problems than to just create paper handouts. All of the software modules we use are available to the students either over the web or on workstations distributed throughout the campus.
- The hardware has to be reliable. For instance, this year the projector has been failing all the time: I start a class, the thing goes down, and I lose time and the interest of the students. Here, technology is more bothersome than helpful.

One thing we learned along the way in this whole software development process was to be careful of intellectual property issues as they relate to funding. We learned this through the experience of a small chemistry department at a nearby university. The department decided to use technology and created some really excellent modules. The university found out about the modules and sought copy rights. Well, the university refused to let anyone see the modules and shut down all communication to the outside world. It took a year of litigation to open up these modules to other chemistry faculty.

At Columbia we decided to keep intellectual property issues in the proper perspective during the development period. The University in the last two years has developed a set of guidelines for intellectual property that has been approved and accepted by the faculty. For example, IR Tutor has been licensed to Wiley Publishers (see next section).

If you have any questions about our project, you can contact me at: turro@chem.columbia.edu
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