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Of Special Interest

Report On "ChemLinks: Changing the Way Students Learn Chemistry"

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ChemLinks is not producing set curriculum, but flexible modules that can be easily modified to fit a particular instructors needs.

ChemLinks is a collaborative effort by over seventy active participants from twenty-four academic institutions to write, test, and disseminate topical modules to be used to teach chemistry in the first and second years of the college curriculum. Twenty-four modules are currently under development and an additional

"ChemLinks: Changing the Way Students Learn Chemistry" by Bill Mungall was presented at the "Day 2 to 40" workshop symposium held May 10–11, 1997. The two-day event was held in the Willard H. Dow Chemical Sciences laboratory building on the central campus of The University of Michigan in Ann Arbor, Michigan. Each of the articles that comprise this issue was written by one of the group of reporters whom I asked to attend each session to take field notes and then follow up with the session leader and participants afterwards.

—Brian P. Coppola, Proceedings Editor

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seven will be started this year. In this workshop the leaders discussed the plan and philosophy behind this project and presented components from two modules as examples.

Descriptive Outline

The ChemLinks coalition presenters introduced themselves to the participants and asked each participant to introduce themselves to the group and give their academic affiliation. The workshop would first present a lecture on the theory behind ChemLinks and then present two currently active modules. ChemLinks is a coalition including faculty from a large number of universities and colleges. It is funded by a three year grant from the National Science Foundation (NSF) specifically for the development of modules whose content will promote chemical education. Ideally these modules will be published in text or some other hard-copy form. Currently, many of the working modules can be found on the web at the address: http://chemlinks.beloit.edu.

Bill Mungall described the structure of the ChemLinks coalition:

> There are several other groups currently funded to work on developing modules. We are working with several of them including the MC^2 consortium as well as the Wisconsin-New Traditions group. There have been many joint meetings between the various module developers and links to their websites can be found at the address listed above. It is important to note that the ChemLinks coalition has a broad collection of members. Members include University faculty as well as college and community college faculty, giving us a wide range of backgrounds and instructional knowledge. This allows the ChemLinks group to tailor the modules to a wide variety of classroom environments. The ChemLinks coalition originally grew out of a group called the Pew State Science Consortium. They were the initial group who wrote the funding proposal and many schools and individuals have been added to the group since its inception. At the University of Chicago and Washington University, materials are being developed and tested. After the initial in-house testing phase, the modules are tested in a broad market base including universities, colleges and community colleges with the module being modified along the way. ChemLinks also coordinates their efforts with groups such as Project Kaleidoscope, the Biological Science curriculum study, Workshop Physics and many others.

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Goals of ChemLinks

- Change the way students learn chemistry. The current way that chemistry is being taught is just not getting through to a large percentage of the students. Through ChemLinks, the effectiveness of the way the material is being presented to the students is being examined very carefully with the hope of creating a much better learning environment.

- Use active and collaborative learning techniques to involve people in the sciences. A goal of ChemLinks is to get all facets of the population involved in chemistry. This includes the general public, minorities, and the kids in the back of the classroom that simply are not involved. By actively engaging them in group activities and eliminating the choice of not participating, ChemLinks hopes to find a way to turn these people on to chemistry.

- Find and present a good model of the *process* of doing science. Recent studies have shown that a large percentage of graduating chemistry students do not see chemistry as an interconnected body of tools for understanding the world around us. Too many are seeing chemistry as a stream of disjointed facts. By creating a model that allows the student to see the simplicity of the molecular world as most faculty do, students might be able to break away from the typical “plug and chug” method of engaging chemistry.

- Increase science literacy for all students. Typically, students have a difficult time relating chemistry to the real world. By increasing their scientific vocabulary and helping them make connections by presenting chemical concepts in a framework that is familiar to them, students will be able to make science and chemistry a part of their everyday life.

These goals are to be achieved by fostering the ChemLinks development program. This program produces teaching materials that are easily adaptable to local needs. ChemLinks is not producing set curriculum, but flexible modules that can be easily modified to fit a particular instructors needs. If a lecturer only has three lectures to present a topic typically presented in five, the modules have the flexibility (and some helpful hints) to accommodate the time constraints. ChemLinks is also current engaged in providing support for faculty that are excited about the implementation and dissemination of these flexible modules. This is already underway with the ChemLinks

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pedagogy committee, which is indeed using new strategies to move forward in teaching methods. Dissemination of modules is already underway. In a joint venture with the MC^2 group, Wiley is publishing several of these modules. The decision on what form this publication should take is still being debated.

Strategy of ChemLinks

Develop Topical Modules For The First Two Years of The Chemistry College Curriculum

This goal has been broken down into three separate areas:

Chemistry and the Environment
Chemistry and Technology
Biochemistry—The Molecular Basis of Life

There are working faculty groups in each one of these areas. The first two groups are primarily to cover the material typically found in a traditional general chemistry course. The last group is to be used in conjunction with one of the first two groups or in conjunction with a traditional organic chemistry course. Developing modules for the Biochemistry group has proven to be very challenging.

Incorporation of New Teaching Strategies

The strategy of developing a module includes not only developing the chemical content of the module, but developing the teaching methodology and creating a model for student interaction. The actual module materials consist of conceptual chemical information in the topical context and laboratory work to reinforce the subject and enhance the student retention of the material.

Evaluation of Interaction Models and Student Learning

How do students learn? Social science professionals were hired to evaluate the student learning process. The scientists were allowed to interact and probe students to get useful feedback. This close relationship allowed the scientists to accurately evaluate whether the modules were actually improving student learning.

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Basic Structure of ChemLinks Module Areas

Chemistry and Technology/Chemistry and the Environment

The pattern so far is that the module titles take the form of a question (see ChemLinks website). Modules are built around an important question that interests students enough to want to research and answer the topical question. The content outlines a method by which the answers to the central question can be discovered by the students. One of the newer modules that was started in the summer of 1997 is a module modeling caves as equilibrium systems. The development group is using caves to show equilibrium effects in temperature, ecology, chemistry and the environment. In some cases modules may be placed in both the Chemistry and Technology section and the Chemistry and the Environment section. In fact, there are cases in which two modules do have some common content. There are currently two acid rain modules in development, and in that case an instructor would most likely not want to use both modules.

Question

1. What is the difference between the Chemistry and Technology and the Chemistry and the Environment sections?

The Chemistry and the Environment section is typically filled with longer modules (typically longer than 3–4 lectures, which is the average for the modules in the Chemistry and Technology section).

Molecular Basis of Life

Many of the modules under this heading are directly pointed towards biochemistry to cater to the large number of biology and chemistry majors who are looking to further their career in medical school. Several of the modules, however, do have a large organic portion to them and depending on the interests of the student, can get into some rather intricate organic chemistry concepts. One of the examples of an organic-intensive module is named “How can we design a therapeutic drug?” This particular module presents some molecular modeling and is currently available through the ChemLinks website. Simple MM2 calculations can be performed using available packages (PC model, CAChe, Spartan, etc.). If a particular institution that wants to use this module is not able to purchase the molecular modeling programs listed, the modeling has already been completed and is available with the important student data on the website. Three-dimensional representations of some of the molecules can be

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manipulated right on the website with programs such as CHIME or RASMOL. We are trying to design these modules so that students from every environment have the same opportunity to discover the underlying principles found in the modules. This particular module covers organic and bioorganic topics that are usually buried at the back of the traditional organic text and never covered. Topics such as carbohydrates, proteins, and molecular recognition, which are usually dropped from the typical organic course (and are of particular interest to the pre-med students), can be incorporated into an organic course framework through the use of this particular module.

Questions

1. How would a teacher go about adding a module such as the one you describe to a typical course?

Pick a module that covers a subject that you would like to cover. Replace the typical lectures that cover the module topic with the module. When teaching the module, remember that teachers of these modules are supposed to be providing inspiration not information; let the students learn on their own. Still, always remember that if this scenario doesn't fit within the framework of your classroom, you should modify the module to your needs. We have found that, typically, it takes longer to cover a topic with a module than it does in a typical lecture setting. Many module testers have seen that they lose content using modules as compared to a traditional course; however, the students will learn the taught modules at least as well if not better and *retain* the information because they learn the information in a context in which they were active and interested.

2. What about the organic questions on the MCAT? Will using the modules make the students less prepared for the organic questions on the MCAT?

During the past decade, the orientation of the organic questions on the MCAT have changed quite a bit. There are now many more application and biochemical questions confronting students, indicating that the MCAT has been shying away from pure organic chemistry questions. In fact, organic chemistry is beginning to be seen as a prep course for biochemistry, which is the class from which the meat of the MCAT material will come. So, the use of the modules has been seen to actually help the premed students, while the modules may actually be doing the organic chemists a disservice.

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3. How are modules tested?

The first test of the module is done by the module writer. We would like to give the module creator some benefit for writing the module, so they get the first chance to try it out. Then the module is sent out for peer review as well as some other field testing. Faculty at somewhere around 7–8 schools are given the module to develop a baseline as to how it is received by both the instructors and the students. After acquiring data from several schools, the module is modified and redeveloped into a robust package and passed to several other institutions for a second and more rigorous round of testing. After this round of testing the module is passed to a central body that gets all of the modules into a uniform format. This last step sometimes cannot be accomplished completely because different modules have different resources, so getting every module into the same format is not always possible.

Drugs from Natural Sources

The presentation shifted to Rhoda Craig who presented this module and described how it was implemented in her classroom.

There are three main groups within this module from which students can choose. Plant-derived drugs, microorganisms, and marine-derived drugs. The instructor makes up a list of drugs in each of the three categories (several examples are supplied with the module). The students are split into small groups (<10), and they choose a drug from each category. The ChemLinks website contains information on a large list of drugs that includes the drug name, the brand name, chemically related drugs, molecular formula, CAS number, IUPAC name, and the source of the natural drug. Students can go the website to gather this information without too much trouble. Once in their groups, the students pick the aspect of the drug in which they are particularly interested (this actively engages them in the decision making process). They are instructed to use the Chemical Abstracts Service (CAS) using the drug’s registry number. This allows the students direct access to the literature (which is very hard to do otherwise). There, the students read the particular abstract and get the “real” journal article. The students are also given a packet of material with background information on their drug as well as some information on a sample drug. Using the sample drug, Rhoda Craig walked the class through what would be expected of them in each of

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several categories in order for them to satisfactorily finish this module. Reports including probing questions on several module topics were due in three weeks and were peer reviewed (double blind).

The sample drug was Taxol, so in the first class the instructor presented the timeline for the discovery and production of the drug. Initially, when this module was constructed, the module called for the students to construct the timeline for their drug first. This worked very poorly and in subsequent trials the timeline was finished last. The students responded extremely favorably to the change, finding it much easier to construct the timeline once they had become more familiar with the drug. The instructor then downloaded the structure of Taxol from the web and went over the isolation techniques, in particular the solvent mixtures used to remove the chemical from the plant material. Next, the discussion turned to how the structure was discovered in the 1970s. Here concepts such as side chains, trans-esterification, organic synthesis, and NMR spectra were discussed. From one drug many chemical concepts can be discussed including acid-base reactions, oxidation-reduction reactions, and other chemical principles.

Another part of this module that allows a fair amount of chemistry to be taught is the discussion of the biological aspects of the drug and how it is activated in the body. The instructor can go through the entire molecule, examining each group. Quite a few types of organic reactions can be discussed during this process. In the section covering this topic, “Biological Mode of Action,” Craig’s students were asked to answer several probing questions in their final report. The Food and Drug Administration (FDA) approval process for each drug was also examined by the students during this module. The instructor led the students through the general FDA requirements using Taxol as an example. The general timelines, all of the approvals needed, and the current status of the drug they were researching were then included in their report. By using newspaper clippings and magazine articles, students can keep this section very current. Another facet of this module deals with the ethics of collecting drugs from plants and other sources. The attitude, until about five years ago, was simply that the plant extract can be obtained by any means necessary and from wherever you can it. If this means the surrounding ecology is destroyed, then so be it. Background research for a debate about these ethical issues was required of the students.

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The students were asked to turn in the references, journal articles, and the questions about their drug from each of the sections discussed above. This information, as well as oral reports, were required at the end of the three-week period. The feedback identified that the students had a difficult time understanding the biological aspects of their drugs. They also would have liked four weeks to complete this module. This particular module was undertaken by the students after seven weeks of a traditional organic chemistry class.

Questions

1. When was the module taught to the students?

In the middle of a second semester organic class.

2. Did the students have the necessary background and the depth of understanding when it came to the complex chemical structures of some of these drugs?

Yes. In fact, I was pleasantly surprised at how well the students picked up the difficult content; however, part of this was due to the small class size. I was able to spend about a half hour with each student going through Chemical Abstracts.

3. It is rather expensive to do online searches of CAS, not all colleges will be able to foot the bill. So how will the students be able to get all of the information they need to complete this module?

All of the material that the students need to complete the module will be posted to the website, eliminating the need to do expensive CAS searches. In our case, the CAS material was available to us, and I felt that the students would benefit from the process of doing a search themselves.

4. It seems like this type of module was quite a bit of work for the instructor.

I didn’t have any graduate students to help with the grading. The peer reviews of the classwork helped; I only had to scan through the work to make sure it had been completed correctly. But, helping the students with the online searches and going through Chemical Abstracts did take a large portion of out of class time.

5. How much time was spent on this module outside of actual class time?

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During the last three weeks of the quarter in which we were working on this particular module, lots of time was spent by the students out of class on weekends and evenings.

6. How did this cut into their other classes?

Well, in past years, they would have been spending a large portion of the time that they were devoting to this module studying for an organic exam. They didn't have to worry about that because we replaced one of the exams with the module.

7. You mentioned that you would like to start the module closer to the beginning of the quarter. How are the students going to deal with the fact that some of the material they need to know hasn't been taught yet?

This was a first iteration for this module and there will be cases that you may have to push up a particular lecture dealing with chemical concepts that will be important for a specific module. If you know a concept will be vital to understanding the drugs in this module, there will definitely have to be some reorganization of the course. You can move some of the easier chemistry that does not pertain to the module to a later time in the course in order to cover the more difficult concepts before the module demands it, but each instructor will tweak the module as they see fit.

The participants began to discuss the ethics of posting copyrighted materials on the web and how exactly the website for these modules could be used without running into copyright difficulties. A participant mentioned that he had learned in another workshop that copyrighted material could be placed on the web if the website was limited for use only to a small group who had been given specific access. This idea of "fair use" would allow a class to assign passwords for the drug material regarding the module, leaving the copyrighted information on the website without fearing copyright infringement. Another participant mentioned that in a workshop that he had attended (and this may have just been the workshop presenters own take on the issue), the presenters had mentioned that it was legal to put copyrighted material on websites as long as the material is changed every two years. After two years it would revert back to being covered under the typical academic copyright rules. The participant felt that this was true even without the "fair-use" password access mentioned earlier.

The participants were then given a quick break before being presented with another working module. Sandra Laursen presented a module that is currently still in the

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developmental stages. Her working title is "You are what you eat, but what are you eating?". Sandra had just finished teaching this module in the Winter 1997 term and, in contrast to the previously presented module on drugs, this food module is presented to the students very near the beginning of their introductory chemistry course.

Food is something that everyone is interested in and is something that we see lots of information about in the media. It is interesting to walk through a health food store and see the health benefits of oatmeal being presented in the same fashion as things like chromium picolinate and all sorts of herbal teas that turned out through tragic episodes to be quite toxic. These products are all described in the same type of pseudo-scientific language and Laursen stated that she would like to give her students the ability to evaluate some of these nutritional and dietary clams. Through this module students can also learn a little bit about molecular structure. Laursen's personal bias is that, while the molecules that the students are presented with in this module can be quite complex, the students have much more interest in them than in the typical molecules they encounter in freshmen chemistry. While PCl_5 is a good molecule to teach trigonal bipryamidal geometry and talk about Lewis structures, she personally doesn't have a good feeling for that molecule and doesn't think the students do either. So why not teach the students bonding and other chemical concepts with molecules that might be a little bit more difficult, but that the students have much more interest in?

This module is intended to help students learn not only some of the general chemical concepts typically covered in a traditional general chemistry course but also to teach the students to assess risk, make informed nutritional judgments, and evaluate the dietary information presented in the media and advertising. One of the interesting topics that the presenter found the students to really enjoy and that was quite helpful from a teaching standpoint was the unit that discussed the diet for a "man-in-space". A *Nature* [1] article from 1965 presented a study in which a purely chemical diet was created for people who would be living in space. There was a recipe which listed all the amino acids, vitamins, and carbohydrates that were needed in order to stay healthy. This method was reported in the study as ideal because this mixture could be dissolved in water and the "man-in-space" would simply drink a certain amount of this material each day. Using prisoners (on a voluntary basis only), the study showed that the subjects who were on the chemical diet stayed healthy and didn't lose body weight. The presenter remarked that this article sparked a very interesting discussion with the students, partially because the recipe included all sorts of different units for the

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students to convert between and partially because the compounds were listed in categories that the students could try to understand. By examining this list the students were able to begin thinking about and understanding how chemists classify compounds. Basic vocabulary issues, which sometimes are very difficult to engage students in, seemed to flow quite nicely from this section of the module. The participants were referred to the other sections of the handout to examine how each module topic was presented to the students. Student feedback and assessment was briefly discussed.

The presenter closed by giving the participants her own assessment of the initial teaching of this module.

- This module should most likely be split into two separate modules because the depth of understanding in several sections was lost in favor of breadth of topics.
- There seemed to be a need to develop activities that would allow the students to develop better skills in the area of data presentation.
- The students had a difficult time making the connection that chemistry can help in terms of making informed decisions in the area of nutrition.
- A better way of motivating the students needs to be found. The common student perception claimed that this module was organic chemistry and therefore too hard. The students felt that they were not supposed to be learning organic chemistry in their first chemistry class and thought that they were being “cheated out” of the traditional general chemistry material.

Workshop Participants

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