ON THE VIRTUES OF INDUSTRY-BASED GENERAL CHEMISTRY

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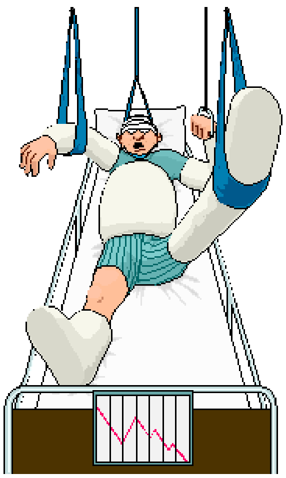
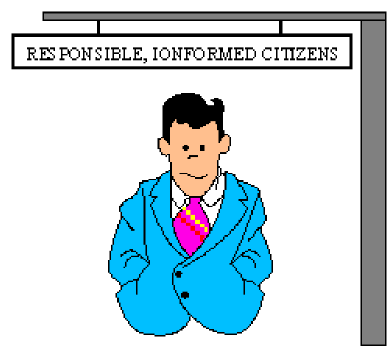
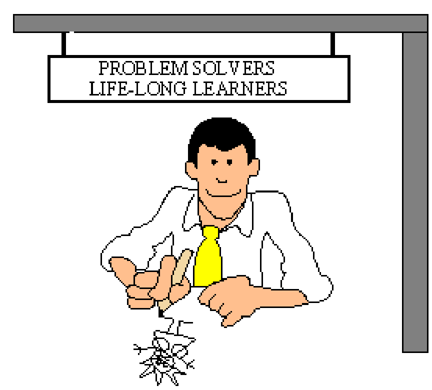


Introduction

The battle over what to teach in General Chemistry, to what depth, and what students should know when they leave General Chemistry, rages on in 1999. Many issues have been debated in this CONFCHEM and other forums and there are many creative minds at all kinds of colleges designing General Chemistry courses to fit the suggested models, to accentuate personal preferences, to apply theories of what ought and what ought not to be, and to accommodate the unique needs of the students. Sometimes there is agreement with colleagues, but often there is not. Sometimes there is agreement with the authors of the textbooks, but often there is not. Sometimes the needs of the students are being met, but often they are not. Oh, the pain!

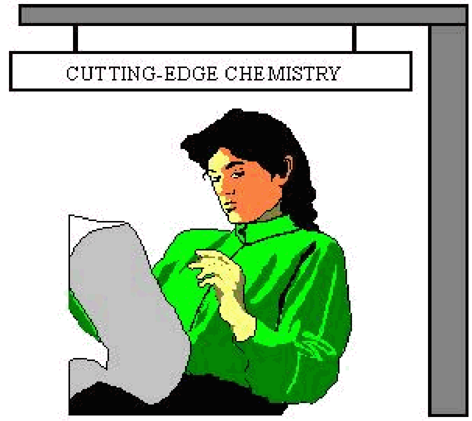


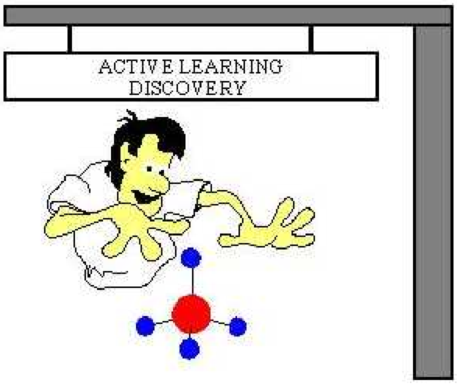
What are some of the guideposts? Some professors are camped squarely under the one that says "we must prepare students to be responsible, informed, and educated citizens." Presumably they are talking about citizens that have no trouble understanding current and future scientific issues when the facts and fancies are bantered about in the media.



Some professors are camped comfortably under the guidepost that says "we must prepare students to be problem solvers and life-long learners." They want to help prepare students to deal effectively with the myriad of decisions they must make throughout their lives - decisions that utilize their abilities to gather the information available to them, to organize it in a logical, coherent fashion, to debate the facts with colleagues, and finally to produce a result that is completely correct and acceptable.

Then there are those professors that are guided by the sign that says: "Teach them pure science; teach them the principles and theories of pure science, so that they can experience the current thinking of scientific experts, the cutting edge of chemistry and modern chemistry research."





The latest guidepost seems to stress technique and methodology in the classroom and laboratory. Some professors feel strongly that the classroom should facilitate active learning and laboratories should be places of enlightened discovery.

Decisions, decisions, decisions. Oh the stress!

Surely these guideposts are not necessarily mutually exclusive. For example, to fashion a citizenry that is responsible, informed and educated could mean that we prepare them to be problem-solvers and life-long learners; that we teach them the principles of pure cutting edge science and do so in an active learning and discovery environment. It becomes a question of which guidepost do we utilize as the pedagogical springboard for our course.

To help us, we have had comprehensive and organized efforts by highly visible and respected groups, especially the American Chemical Society (ACS) and the National Science Foundation (NSF). For example, with NSF funding, the Division of Chemical Education of the ACS formed the Task Force on the General Chemistry Curriculum which produced a document (1) in 1994 announcing their recommendations. A committee of the NSF itself conducted an "intensive review of the state of undergraduate education in science, mathematics, engineering, and technology (SME&T) in America," which, in 1996, also produced a report (2). After examining these reports, and after 22+ years of experience successfully training chemistry technicians in a community college, ***I have concluded that a useful strategy would be to approach General Chemistry by communicating to the students at every juncture what the current topic has to do with what real-world chemistry professionals do.*** If we do this, everything else will fall into place, including what topics do we emphasize and what topics to we de-emphasize or eliminate; what topics relate to an informed citizenry; what topics emphasize problem solving; what topics relate to pure cutting edge science; and what topics lend themselves to active learning and discovery. Say goodbye to the stress and the pain!

What Chemists Do

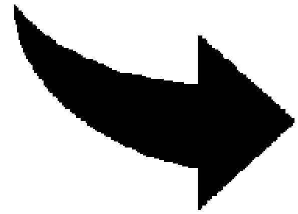
In my 22+ years teaching in a community college program whose purpose is to prepare chemistry technicians for the real world of work, I have had to become keenly aware of what chemistry professionals do in this real-world (3). Such an awareness is required in order for me to be effective in my job. And I have heard General Chemistry curriculum reformists often refer to "what chemists do" to be a concept that should be utilized in the process of reform. This concept shows up in the reports I referred to earlier.

Shaping the Future

New Directions for General

New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology

Chemistry



In the ACS Task Force report (1) a list of goals for a General Chemistry course (4) appears. The very first goal reads as follows: "Introduce students to the process of science as it applies to chemistry and **what chemists do**." In the "Recommendations" section of the Shaping the Future report (2), the following is the third recommendation listed for faculty members: "Build into every course inquiry the process of science (or mathematics or engineering), a knowledge of **what SME&T practitioners do**, and the excitement of cutting-edge research."(5) But I have also noticed that while faculty members sometimes say they apply the "what chemists do" idea in their classes, more often than not these applications accentuate the cutting edge research concept too much and the students, because of the often abstract nature of the research and the impossibility of applying it to their lives in some way, look at it as just another course to get through.

The workplaces of most modern chemistry professionals are the analytical laboratories of the chemical process industries or government agencies. **What chemists do** is often quality assurance, which includes the acquisition and preparation of samples, the analysis of samples using standard operating procedures (SOPs), data handling, and the reporting of results to colleagues and customers. The problems they solve relate to the customer complaints, out-of-spec materials and products, the proper calibration and operation of instrumentation, the policies and procedures relating to their safety and health, the adherence to government regulations known as Good Laboratory Practices (GLP), and the appropriate laboratory operations relating to labeling, sampling handling, waste disposal, documentation and report writing. This is a sampling of **what chemistry professionals do**.

WHAT CHEMISTS DO

Analytical Chemistry
Quality Assurance
SOPs
Data Handling
Sampling
Out-of-Spec Materials
GLP
Calibration
Safety and Health
Labeling
Waste Disposal
Report Writing

I believe that an industry-based general chemistry curriculum that brings to light what these chemists do, especially in the context of the consumer products and applications that relate to the personal lives of students, can go a long way toward achieving the goals of the ACS and NSF and also has the potential of transforming the negative image of the General Chemistry course.

Communication and Teamwork

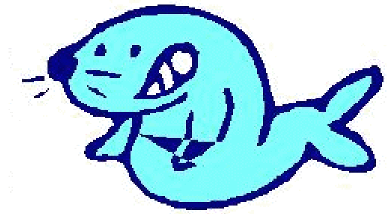
In addition to the quality assurance issues mentioned above, industrial chemical professionals are quick to inform us that communication and teamwork are practiced by scientists in industry. Thorpe and Ullman wrote of this in their paper (6): "Industrial scientists and engineers spend a significant portion of time writing periodic reports that summarize their work, proposals justifying the purchase of instruments or suggesting research programs, development plans and appraisals for themselves and their subordinates, analytical reports, and memos. Each document must be written to convey conclusions, recommendations, and technical information to the target audience in ways that they clearly understand." Concerning teamwork, these authors state the following: "The corporate world is multinational, multidisciplinary, multiracial, and multi-any-else-you-can-think-of! Success depends on effective collaboration with all of these people."

The Shaping the Future document (2) is in sync with this. It states the need for the development of communication and teamwork skills in the fourth goal for SME&T faculty (5): "Devise and use pedagogy that develops skills for communication, teamwork, critical thinking, and lifelong learning in each student."

Making My Course "Industry-Based"

Probably all of us are products of traditional Baccalaureate and Masters or PhD programs and most of us have used traditional textbooks for General Chemistry since our teaching careers began. As General Chemistry goes, it's all we know. Most of us have no true experience in an industrial workplace. The suggestion to make a course "industry-based" may be viewed as a proposal that cannot be carried out. Not many of us have known the life of an industrial chemist and cannot relate to this career. We'd be like a fish out of water. We just want to continue in our current vein, adapting our courses to the available textbooks, being comfortable with the traditional approach developed through the years by academic chemists, and ignoring what real-life chemists do.

Would you feel like a fish out of water?



That was my answer to General Chemistry until about five years ago when I decided it was time to make my course more relevant to the technician trainees in my course. The National Science Foundation agreed and, through the Advanced Technological Education program, funded a series of two projects (7) at my college for creating the industry-based first-year course for the students in 2-year college chemical technology programs. Approximately mid-way through the work, I came to realize that this could be the answer to the woes of General Chemistry courses everywhere. I believe it represents a painless transition from the traditional course to one that could achieve most, if not all, of the modern goals of the ACS Task Force and the NSF's Shaping the Future report.

The process does not mean introducing new and foreign material that few of us would recognize. Rather, it takes traditional topics and wraps them in examples and scenarios from industry, and relates them to consumer products that come from industry. This helps bring the chemistry alive for students (and faculty too!). Any topics for which an industrial example or scenario could not be easily discovered are de-emphasized or eliminated from the course. In the textbook that is being created (8), the "wrapping" takes the form of an industrial example or scenario included on about every fifth page or so that ties the current topic to the workplace of chemistry professionals. Included in these side-boxes are homework or class discussion exercises that strongly encourage the students to think about the scenario in greater depth, to do some research outside of class (resources, including Internet sites, are often suggested), and to submit written, and sometimes present oral, reports (communication!!) on their findings. In my class, I ask the students to choose an exercise from all those presented in a given chapter and then do the research and write or present the report. This means that they will read all of the examples (in order to sometimes find the one that seems to be the easiest) and thus learn at least a little about why each topic is included in the course (there is one side-box titled "Why Study This Topic" in each chapter) and why it is good for them to understand it. There are additional choices included at the end of each chapter.

Using this model, if students begin to wonder why a notion as abstract as electron energy levels is important, the answer becomes clear in the industrial scenarios involving chemical analysis of samples via atomic spectroscopy. If they become bored with our discussion of stoichiometry, they become enlightened by the industrial scenarios that discuss how chemical formulas of new compounds are determined by mass spectrometry, how the percent of an element in a material is determined via elemental combustion analyzers, or how the determination of the percent yield in an organic synthesis can mean whether a reaction studied in industrial R&D will be scaled up for mass production. If they question the relevance to their life of the use of the combined gas law for the correction of a gas volume to STP, for example, they discover that the calculation used in the EPA procedures for the analysis of air for toxic gases requires it.

Hmmmm! Why is this important?

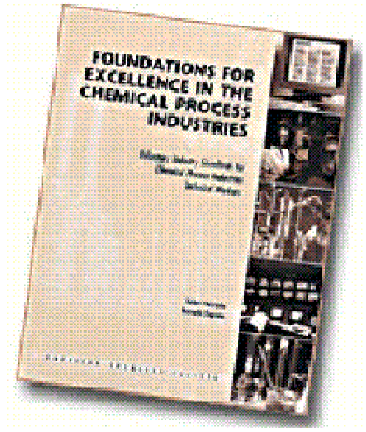
Laboratory and CD-ROM

The laboratory manual (9) and CD-ROM that will accompany the textbook have been described elsewhere (10). Both of these ancillaries place the students into fictitious industrial scenarios in which a problem must be solved either by performing laboratory work in the college laboratory (SOPs found in the laboratory manual), or by seeking out and examining data and information included on the CD. The communication and teamwork aspects of work in industry are emphasized. In the laboratory, they must frequently work in teams to solve the problem. I believe this design for the laboratory fits the concept of enlightened discovery mentioned at the beginning of this paper. Students are also required to write memos to the company "clients" to report their findings. On the CD, students acquire information from consultants working as part of the team. They also must keep journals to be viewed by their supervisor (instructor). All of this helps them understand that communication skills are needed in industry and helps them to develop these skills.

I love to write chemistry memos and reports.

Pondering the Change

Perhaps you're now thinking, "Gee, this sounds appealing, but I feel I just don't have a good feel for what industrial chemistry professionals really do and so I'm not qualified to teach in this way." Fortunately, a huge project undertaken by the American Chemical Society and completed in 1997 provides a mound of information for us to ponder. Standards for the education of chemistry technicians in two-year college chemistry technician programs were created after a three-year undertaking in which



the tasks that chemistry professionals perform on a daily basis were identified and documented. Popularly known as the Voluntary Industry Standards and found in a subsequent publication of the ACS (11), these standards list competency after competency required of the chemistry professionals often referred to as chemical technicians. Take a look at what these chemistry professionals do. If we want to use "**what chemists do**" as the springboard to a course that forms an enlightened, problem-solving citizenry that can be adapted to active learning and discovery, then this document would be a wonderful resource.

Conclusion

Revising a General Chemistry course to make it industry-based does not have to mean learning industrial chemistry. It can mean teaching the traditional topics but putting the industrial spin on them with industrial scenarios that students must research. It can mean laboratory activities in which they perform the laboratory work needed to solve a fictitious industrial problem, the results for which are then reported to the "client" via a written memo. I believe it is a good plan because it teaches the students **what chemists do**, which is a recommendation of both the ACS General Chemistry Task Force and the National Science Foundation's Shaping the Future document, and can be used as the springboard for the other important goals we have for our courses.

Acknowledgments

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