The Case for Reform of the Undergraduate General Chemistry Curriculum

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1 AUTHOR:

Melanie Cooper
Michigan State University

Editorial

The Case for Reform of the Undergraduate General Chemistry Curriculum

This month, the National ACS meeting in San Francisco offers chemistry educators the opportunity to meet and discuss the important issues of our field. One topic that is ripe for debate is general chemistry, its role in the curriculum, and how (or even if) it should be changed so that students acquire a robust and relevant understanding of chemical principles.

General chemistry is the college course in which most students begin and end their chemistry studies. While required in a wide range of degree programs, including engineering and sciences, it would be fair to say that most students and many faculty find the course to be less than satisfactory, and there have been numerous calls for reform *(1−4)*. Those involved mainly agree that the way general chemistry is typically taught engenders several problems. Specifically, general chemistry:

- Covers too much material, thereby sacrificing depth for breadth
- Is taught as if students were chemistry majors, ignoring the fact that most students are not
- Takes approaches that are generally ineffective at encouraging student understanding of basic concepts, regardless of whether those students are chemistry majors
- Uses a course or curricular design inconsistent with both the realities and the research on how students learn
- Is not usually taught in a pedagogically sound (that is, effective) manner
- Often fails to engage student interest: some studies indicate *(5)* that students emerge from general chemistry courses with a less-expert concept of what chemistry is and a lower satisfaction with chemistry than when they began

The current incarnation of general chemistry has its roots in the 1960s as a response to the perceived need for a more robust and rigorous technical education. In an attempt to provide a theoretical basis for what was seen as a largely descriptive course, a more mathematical and theoretical curriculum was developed, largely through the addition of topics from physical chemistry *(6)*. The resulting curriculum is the one we see today, with a few exceptions.

Over time, new content has been added to the general chemistry course. For example, texts from the early 1960s generally do not mention entropy, free energy, or molecular orbitals, but today's textbooks do. At the same time, little content has been removed. The texts of today are larger and more encyclopedic than ever, so that the typical course often appears to the novice as a disjointed, brisk trot through a host of unrelated topics. One common response from students interviewed as to what they remember from general chemistry is that they detected no overarching principles or themes.

While strong networks of faculty have implemented reformed, interactive pedagogies such as process-oriented, guided-inquiry learning (POGIL), peer-led team learning (PLTL), the use of clickers, and problem-based learning *(7)*, the underlying content and overall structure of most general chemistry courses have changed little over the last 40 years. This is despite the often-dramatic changes in the needs of the students required to take the course. For example, general biology has shifted from being a largely descriptive course to one that provides an organizing conceptual framework based on physiochemical principles. Engineers increasingly work at the nanolevel, where an understanding of how and why molecular structure affects the function of materials is critical. For such students, general chemistry's traditional focus on stoichiometric calculations and the gas laws is too often irrelevant. Even chemistry majors need a robust understanding of fundamental chemical principles. We should provide this, but often do not.

A number of looming changes may force us to become more reflective about how and what we teach. In the future it is unlikely that we will be able to "count on" a captive audience of general chemistry students (and organic chemistry students, for that matter). Most large chemistry departments depend heavily on the general and organic chemistry courses to support the departmental operations and funding for the TA budget. Accrediting agencies and professional schools are increasingly requiring outcomes-based assessments of competencies. In other words, students may be able to demonstrate a skill or understanding of a concept without being required to take a course in that subject. The scarcity of discretionary credit hours in every curriculum may make two (or four) semesters of chemistry a thing of the past. We have to become more responsive to the needs of our students or risk becoming obsolete (at worst) or marginalized, at best.

Over the years, many initiatives have aimed to change general chemistry. Some have produced exemplary materials and improved outcomes, but none have brought about the type of systemic reform that might be hoped for. Why is this? Why, after millions of dollars and the efforts of hundreds of curriculum developers, researchers, publishers, and teachers of chemistry, is general chemistry still such a problematic course? Why is there such resistance to change? It is not as if the design of the course were intentionally well crafted in the first place. Alex H. Johnstone, winner of the 2009 ACS Award for Achievement in Research for the Teaching and Learning of Chemistry *(6)*, points out that we have been teaching our current version of the general chemistry course for so long that we have forgotten why, for example, Chapter 4 is always solutions (if there ever were a reason) or why the coverage of gases comes before a discussion of entropy. The reason mainstream textbooks all look more or less the same (except for some chapter juggling) is not because publishers are content with the status quo but rather because they provide the texts instructors believe they want. We have only ourselves to blame.

The ACS Committee on Professional Training has had relatively little to say about general chemistry. This is because the committee is more concerned with the education of professional chemists, despite the fact that building on a weak foundation is not the generally accepted approach to building a strong structure. It is time, however, for ACS to take a clear stand on what

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a general chemistry curriculum should entail, both in terms of content mastery and demonstrable skills. The ACS's Society Committee on Education has voted to convene a task force (made up of representatives from areas whose students take general chemistry, curriculum developers, chemical education researchers, and publishers) to investigate the possibility of developing a set of ACS standards for general chemistry courses. These new standards would articulate a set of concepts central to the understanding of chemistry and common to any general chemistry course. Rather than serving as a laundry list of topics to be taught (like many state standards), the new standards would provide a clearly argued focus on the foundational ideas and skills that we as chemists agree are central to fluency in general chemistry. We might hope that such standards will have far-reaching effects, including promoting interest in chemistry as a career, increasing student understanding and appreciation of key chemical concepts, and providing a focus for curriculum developers, publishers, and researchers.[1] Extracting the important concepts from the mishmash that comprises the traditional general chemistry course would provide support and focus for a range of activities, including assessment (e.g., the ACS Examinations Institute), text adoption, and support for innovative curriculum development.

What is the alternative? Just this: we can sit and wait for our own obsolescence.

Note

1. One possible model for these standards is the recently released College Board Science Standards for College Success: http://professionals.collegeboard.com/k-12/standards (accessed Jan 2010). These were developed in conjunction with the ongoing AP redesign project. The chemistry standards are based around three "big ideas": The structure of matter; matter and change; and energy and change. Each standard has three to six objectives, each of which articulates essential knowledge needed to understand a particular concept. What differentiates these standards from others is that each objective is accompanied by performance expectations, i.e., what students should know and be able to do with that knowledge.

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Melanie Cooper is at Department of Chemistry, Clemson University, Clemson, South Carolina 29634-1905; cmelani@clemson.edu.