1 / VOL. 3, NO. 1
THE CHEMICAL EDUCATOR

ISSN 1430-4171
http://journals.springer-ny.com/chedr
10.1007/s00897980162-X

Of Special Interest

The -ills of Educational Reform

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Commitment to reform is like any other change: it requires more than the decision to do so in order for it to happen.

Many instructors have sincerely accepted problem solving and critical thinking as instructional objectives. This kind of language, especially notions of the liberal-arts values of taking college classes, is used in compelling "first day of class" pep talks. Increasing the scientific literacy of an educated voting citizenry has also been persistent "Day 1" rhetoric, beginning with preparing students in the post-War Atomic Age and continuing through today's concern for environmental and biotechnological issues. Unfortunately, too often little happens on days 2 through 40 (a typical number of class meetings in a semester) to fulfill the expectations and promises laid out on the first day. Why is this connection so difficult to achieve? Part of the answer can be found in the difference between the intellectual change that characterizes

"The -ills of Education Reform" presented and reported by Brian P. Coppola 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.

—Brian P. Coppola, Proceedings Editor

ISSN 1430-4171
THE CHEMICAL EDUCATOR
http://journals.springer-ny.com/chedr

S 1430-4171 (98) 01162-X

Day 1 when an instructor may possess the knowledge (skill) for what needs to be done and the behavioral changes (will) that are needed on Days 2-to-40. A brief historical application of these ideas as they pertain to the current cycle of chemical education reform is provided.

The Gap Between Science and Science Instruction

The undergraduate chemistry curriculum is at a familiar juncture in science instruction: the point at which the maturity and complexity of a science begin to substantially increase the distance between contemporary activity in the field and its introduction to students. Introductory physics and biology courses are often static and quite uniform across the country, and admittedly so are the topics in many General Chemistry courses. A common strategy being used to reform General Chemistry programs, as posited earlier [1], is to overlay a static group of topics with a new context (such as materials, biological, or environmental sciences). Is atomic structure, stoichiometry, electrochemistry, nuclear decay, the gas laws, and significant figures to define the introduction to chemistry the way Newtonian mechanics defines introductory physics? Is chemistry like calculus: a defined set of skills that simply needs to be learned in order for a student to go on to other courses? Or, as argued below, are the reasons for the current look of General Chemistry strongly attached to the needs of the engineering disciplines that emerged at the turn of the century? If so, then what of the needs of the diverse clientele who comprise a much larger fraction of introductory chemistry classes in the 1990s and whose literacy in molecular structural systems and their transformations can only come from courses offered in chemistry departments?

The look of introductory chemistry today can be traced back to three things: the Industrial Revolution, the rise of the Engineering disciplines, and the Atomic Structural Revolution-namely, the discovery of electrons and the development of quantum mechanics. The second significant revolution in the history of modern chemistry is the maturing of the molecular structure–reactivity model for which the chemistry of the main group elements has provided the most sophisticated picture. I suggest that the peak era of the Molecular Structural Revolution be assigned to the 1950s, and includes the development of techniques such as X-ray crystallography and applied nuclear magnetic resonance spectroscopy and the proposition for double-helical DNA. During this time, organic chemistry was transformed by the work of physical organic chemists. Stereochemistry, conformational analysis, and the

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ISSN 1430-4171
http://journals.springer-ny.com/chedr
S 1430-4171 (98) 01162-X

implications from applied kinetic and thermodynamic investigations became immediately integrated into the operations of the science as well as into introductory instruction. What was once a seemingly endless array of empirical relationships coalesced around a surprisingly few mechanistic principles. The excitement generated by molecular biology and materials science is really the richness of structure–reactivity relationships that have made chemistry the central science in the 1990s. There are many questions to consider. Is it rational to move introductory chemistry instruction along with these advancements in the discipline? Is it reasonable? Is it possible? Is it desirable? Changes in introductory instruction after the Atomic Structural Revolution happened rapidly, within perhaps a 20-year period. No substantial response to the comparable Molecular Revolution has happened after nearly 50 years. Were these former changes any less dramatic or putatively less difficult for students than the introduction of structural chemistry would be today? Perhaps responding to a second revolution is actually more difficult than to the first. And what of the inevitable next advancement? I posit that we are at the beginning of the Supramolecular Revolution, which might include the development of host–guest chemistry (and its 1987 Nobel Prize), computational models for large molecular aggregates, and understanding of the basis of molecular recognition. Does general chemistry provide the only entry into these topics? Does it at all? The program we began in 1989 at The University of Michigan, beginning with contemporary main-group chemistry as the basis for the entire introductory course, is indicative of giving molecular (and even supramolecular) topics their deserved place in the chemistry education of all students. For a provocatively new perspective on the organization of chemical sciences that could be used to inform a direction for new curricula, readers are directed to two outstanding books written by Williams and Fraústo de Silva [2, 3].

Rediscovery and Reinvention

The ferment associated with recent activities in undergraduate chemistry instruction, when examined from a 100-year perspective, is shadowed by an important reality: although we live in interesting times, they are not new times. The lack of any informed training for future faculty in science education means that our profession meets at least one definition of purgatory: we are condemned to repeatedly relive the past. Active public discourse on teaching and learning in first-year college chemistry doubtless began as soon as specific courses of study for undergraduate chemistry degrees

ISSN 1430-4171
http://journals.springer-ny.com/chedr
S 1430-4171 (98) 01162-X

emerged in the nineteenth century. As the twentieth century began, the nature of identifiable "Freshman Chemistry" courses was as much a topic for discussion as it today. By 1924, evidence of this interest can be found in the contributions to the first few issues of *The Journal of Chemical Education*, where articles have titles that sound as topical in 1997 as they must have in the 1920s: "What We Teach our Freshmen in Chemistry" [4], "A Deviation from the Stereotyped Method of Teaching Freshman Chemistry" [5], "Creating Interest in Freshman Chemistry" [6], and "Meeting the Needs of the Freshman Chemistry Class" [7].

In the 1920s, although published papers addressing organic chemistry instruction were not as common as those concerning general chemistry, there were some discussions on the role of organic chemistry in the general chemistry program. In 1927, Frank C. Whitmore published a report on a symposium he organized for the American Chemical Society meeting (April 1927 in Richmond, Virginia) titled "How Much Organic Chemistry Should be Included in the General Chemistry Course?" [8].

> What is the purpose of the course in general chemistry? For perhaps ninety per cent of the students this purpose has very little to do with professional chemistry, either as applied in chemistry or in pursuits such as engineering and medicine, which use chemistry as a tool. Most of the students are preparing for some life activity which can be carried on rather successfully without any chemistry but which will be more interesting with a slight knowledge of chemistry. For this class of students it is important to give in the general course a few of the fundamental conceptions of organic chemistry.

In the Whitmore symposium, J. S. Guy (Emory University) asked:

> Why not make the first course in chemistry a course in elementary organic instead of inorganic? Inorganic chemistry is coming to contain so much physical chemistry and other complicated things that it is beyond the understanding of the freshman. Elementary organic chemistry is not quite hard enough…yet. I think I shall try such a system next year.

The question raised by the Whitmore Symposium, updated by 70 years, has been revisited by three or four generations of chemical educators and remains unanswered: Is a physical chemistry context still the best choice for introductory college instruction in the 1990s?

Authors have also suggested that organic chemistry provides instructors with the advantage of introducing students to the understanding of an authentic subdiscipline

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(the same argument we at the University of Michigan rediscovered in 1989). Whether it was Degering in 1938 [9] or Smith in 1967 [10], chemists have described imaginative instruction resulting from the organizational interplay between specific, yet representative, cases and a few, yet broadly applicable, general concepts, which is characteristic of organic chemistry. In 1939, Brewster argued this point strongly [11]:

> As teachers of organic chemistry, we are likely to consider ourselves as chemists, rather than as educators. Few subjects are better adapted to this purpose [the development of one's reasoning power] than ours [organic chemistry].

That same year, Henry Gilman expressed an even stronger viewpoint [12]:

> A course is not weakened by being made interesting, and there is much of historical and practical interest in organic chemistry.

Form and Reform

How do we break free of repeating cycles of reinventing reform in each generation? The first answer is to stop being inattentive to the pedagogical education of the next generation of faculty. As alluded to earlier, informed professional development of faculty for instruction is lacking. Mid- to late-career faculty need to rediscover or reinvent much without any provision for educating the next generation. Although it is possible to create a positive spin on this situation (it allows for fresh perspectives and new ideas), it is nonetheless not the way in which scholarship is developed in the disciplines of postsecondary education. A more compelling reading of the problem, I think, is the systematic devaluation of the teaching and service functions of the professoriate due to a half century of meritocratic faculty evaluation. The second answer comes from Larry Cuban: the process of reform is itself unexamined. In his essay, “Reforming Again, Again, and Again,” Cuban [13] concludes that:

> Waves [of reform] occur on the surface [of formal education] and, in some instances, programs, like the skeletons of long-dead sea animals, get deposited on the coral reef of schooling…[yet reform itself goes critically unexamined]….I end with a plea for rationality, that is, serious thinking about rational and nonrational organizational behavior....If we do not heed the plea, we will continue to mindlessly speculate, and as Gide observed: “Everything has been said before, but since nobody listens, we have to keep going back and begin again.”

ISSN 1430-4171
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S 1430-4171 (98) 01162-X

Cuban is not a pessimist. He raises the issue of “organizational behavior,” and the significance of affective dimensions in understanding reform. “Reform,” after all, is part of the broader landscape of “change,” and change sits at the core of “learning.” Recommendations to pay attention to both the intellectual and affective attributes of learning have emerged from educational psychology. These have had the most impact at the precollege level; they are barely detectable at the college level; and they have had no penetration at all in faculty development and administrative systems. Advocates for distance learning, for example, have historically overemphasized the delivery of information and are beginning to relearn that there is something more than simple proximity that characterizes person-to-person interactions.

Skill and Will

Commitment to reform is like any other change: it requires more than the decision to do so in order for it to happen. Scott Paris, a psychologist at the University of Michigan, has nicely capsulated two distinct interactions, namely the “skill” and the “will” for what is called strategic learning. Paris originally studied the reading ability of precollege children [14, 15]. It is not enough to what to do and how to do it, but one must also want to do it [16]. These ideas about learning (as change) are generically useful. In addition to the intellectual (skill) and behavioral (will) dimensions, one of Paris’ colleagues has also suggested that reward (thrill) should be included, too [17]. By analogy, the distinction between skill and will can be thought of as the “overweight-sedentary-smoking-physician” scenario: one can possess all of the necessary intellectual skills to make a good choice, and yet enacting it still needs to be considered quite independently from the original decision. Educational psychologists have used these ideas to remind educators that motivational issues play a significant role in learning.

I will now take a different allegorical look at how these ideas are intertwined and their possible place in thinking about teaching and about reform. Imagine I am holding a class (for you, my readers) in something I can do reasonably well: weightlifting. I do not think I need to “teach” you all that much about how to lift weights, understanding the skill part is-shall I say-intuitively obvious: lift the weight. If we all walked over to the weight room at one of the recreational buildings on campus we could all take my

ISSN 1430-4171
http://journals.springer-ny.com/chedr
S 1430-4171 (98) 01162-X

Bench Press Test to examine our abilities. Because I am a good coach (a popular word in education, now), I will show you how the bench press is done. Then I would have you lie down on the bench, under a bar loaded with 245 pounds, and (because I am a good coach) help you lift it off the stand. Then I would let go. I am confident that I could assign some pretty accurate grades based on what happens next. Some of you will get an "A" grade. I would surely tell my colleagues with pride: "See, they could do it! My teaching was good—and the skill was clearly there. It is possible, on second thought, that we ought to perhaps make this a pass/fail course. The rest of this class just did not seem to be trying hard enough. I have heard Paris talk about that motivation stuff: If they had really wanted to get that "A" they could have—they just were not trying." The caution here is not to confuse the inadequate attention to the development of students' skills by attributing their failure to their lack of will. Almost paradoxically, reacting disproportionately to the success of a few in the face of general failure is similar to overreacting to a few negative comments in the context of a collection of otherwise excellent evaluations [18]. A common thread is to want to have done the right and proper job for those who count on us to help them develop their abilities.

Beyond the obvious analogy to classrooms of students, there is also a connection to the curriculum reform movement. In particular, reform-active faculty have an obligation to their work (and the strength they have developed from it) that goes beyond hefting it into place for others either to lift with success or to collapse beneath. Reformers and innovators not only need to describe something that has worked for them and why, but also to dissect out the generalizable features that are not tied to their own classrooms, their own institutional settings, and their own motivations. Although innovations are often designed and intended for "adoption," both innovators and users of innovations should more often think of "adaptation" as their goal. Bringing change to one's teaching is always constrained by idiosyncratic classroom, institutional, and motivational situations. It requires more than just the decision to make a change. As adaptations are created, new ideas emerge. The in-depth experience of the innovator is not only needed as a coach, but also as a spotter! Our students need us to be spotters, too.

A spotter is a more engaging metaphor for the role of a more experienced learner in the education of others than is a coach. Spotters are peers, doing the same activity but frequently at a more complex level. Coaches are more often off to the side, or even in

ISSN 1430-4171
http://journals.springer-ny.com/chedr

S 1430-4171 (98) 01162-X

their offices, administering from a distance. Spotters can take on some of the traditional duties of a coach, as necessary (motivational: “Come on! You can do it!;” educational: “Here’s another way to do it.;” correctional: “Try doing it this way, not that way, or else you’ll get into trouble later.”). Spotters, unlike coaches, are not at all there to make rankings and judgments, and thus they encourage the learner to take risks. Spotters are a safety net; they intervene when needed and provide encouragement throughout. They know when a task may be beyond the ability of the learner—and sometimes the spotter assists throughout the entire task so that the learner gets a feel for the part that they can accomplish even though it is overwhelming. Regardless of good will, a coach also has a duty to a larger community for ranking the trainees, to decide who gets to represent the work of the group in some other setting, who is allowed to go on to the larger competitive arena to earn local or national rankings, and so on. A spotter does not have to be a person of necessarily superior ability in order to provide assistance, either. Experienced practitioners also seek to improve their skills, and although they carry the majority of the burden, the less experienced spotter who understands the spotter’s role can be as useful to that person as any other. Together, these peer-based teams consistently accomplish more than either alone, and their activity is always to the benefit of both for improving their abilities. Indeed, the culture within which spotters operate understands the tangible value of working with others. Regardless of the progress that can be made by an individual working alone and at any level of experience, the same investment done in conjunction with a spotter will always result in higher achievement. A spotter's action is miraculously ego-free and altruistically given toward the common good. There is no expectation that a person who spots for another need ever get reciprocal help from the one who has been assisted; yet it is equally true that the spotters in this situation are confident that there will be someone to assist them when the time comes, and that the person who was spotted will indeed do the same when called upon. On reflection, although the coaching metaphor has been a useful way to move instructors away from “teaching” towards “facilitated learning,” the practice of coaching may be more like the traditional role for “teaching” than is intended.

In adapting reform, the skill and the will relate to your ability to decide to take on an idea and then to do something with it. These two ideas can be more concretely associated with instruction. Linking what we want to do in our classrooms with our own teaching behaviors is at the core of reform. Just as we expect from our

ISSN 1430-4171
THE CHEMICAL EDUCATOR
http://journals.springer-ny.com/chedr

S 1430-4171 (98) 01162-X

students-and even the long term smoker who decides to quit-we must also understand the difference between the skill needed to accomplish a change and the will to accomplish it. Many instructors have sincerely accepted problem solving and critical thinking as instructional objectives. This kind of language, especially notions of the holistic or liberal arts values of taking college classes, is used in compelling "first day of class" pep talks. Increasing the scientific literacy of an educated voting citizenry has also been persistent "Day 1" rhetoric, beginning with preparing students in the post-War Atomic Age and continuing through today's concern for environmental and biotechnological issues. Unfortunately, too often little happens on days 2 through 40 (a typical number of class meetings in a semester) to fulfill the expectations and promises laid out on the first day. Why is this connection so difficult to achieve? Part of the answer can be found in the difference between the intellectual change that characterizes Day 1, when an instructor may possess the knowledge (skill) for what needs to be done, and the behavioral changes (will) that are needed on Days 2 to 40. A teacher's behavior has consequence. Some of the most important lessons students learn from their instructors are the ones they learn "by example." There are no value-free environments; in education, value-based reasoning can only be concealed or ignored. How instructors present their interaction with the subject matter cannot be neutral, and a conflict between Day 1 and Days 2 to 40 in fulfilling the promised expectations must naturally begin to erode confidence, trust, and credibility. Like it or not, the lessons we provide for our students cannot be confined to the subject matter.

Engaging the behavioral and motivational dimensions of teaching does not negate the need for progress in developing new ideas! Many instructors spend a great deal of time on producing and describing curriculum plans that are effective in their classrooms and laboratories. Outside of the relative privacy of developing good ideas in our individual classrooms, however, we must also address how to more effectively sustain that progress when it leaves our direct influence. Sometimes as coaches, sometimes as spotters, our expertise must be engaged at different levels as our ideas become the strengths displayed by others: faculty and students alike. Otherwise, reform will end up as the work of the innovative few, adaptation will be a well-intended failure, and another generation will be required to reinvent the wheel.

ISSN 1430-4171
http://journals.springer-ny.com/chedr
S 1430-4171 (98) 01162-X

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