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In the Classroom

# Progress in Practice: Organic Chemistry in the Introductory Course

**BRIAN P. COPPOLA**
The University of Michigan
Ann Arbor, MI 48109-1055
bcoppola@umich.edu

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

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 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 is today. By 1924, evidence of this interest

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*Individuals involved in curriculum design often introduce new, modified, or applied ideas about instruction that span from classroom methods to philosophies of education. In this series, we examine progress in chemical education that is related to actual practices, and where many recommendations have originated from areas in higher education that exist alongside of and overlap with chemistry. Rather than an exhaustive review, we will select examples, background, and vocabulary that may either invite interested newcomers to explore a different area in their teaching, or provide language and precedent for individuals who wish to contextualize ideas they have developed independently.

*—Brian P. Coppola, Series Editor*

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can be found in the first few issues of the *Journal of Chemical Education*, where articles have titles that sound as topical in 1996 as they must have in the 1920s: "What We Teach our Freshmen in Chemistry" [1], "A Deviation from the Stereotyped Method of Teaching Freshman Chemistry" [2], "Creating Interest in Freshman Chemistry" [3], and "Meeting the Needs of the Freshman Chemistry Class" [4].

In the 1920s, although published papers addressing organic chemistry instruction were not as common as those concerning general chemistry, there were some discussions of the role of organic chemistry in the general chemistry program. In 1927, Frank C. Whitmore published a report on a symposium he organized for an American Chemical Society meeting (Richmond, VA, April 1927) titled "How Much Organic Chemistry Should be Included in the General Chemistry Course?" [5].

> 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 [5]:

> 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.

Ten years later, in 1938, Wakeham anticipated a time when organic chemistry would take a share of the introductory course [6].

> Organic chemistry is of just as much general importance as inorganic chemistry. The time will probably come when high-school and freshman courses will be divided about half and half between the two subjects.

The reasons for including organic chemistry that were stated and alluded to by Whitmore, Guy, and Wakeham, such as relevance and accessibility of the subject matter, are still used today, and have been extended to include topics such as environmental chemistry and materials science in the introductory program. Yet,

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identification of interesting factual content is not enough. The organization of the subject matter and how it is instructed is fundamentally important to its potential use in an introductory course. Roger Adams recognized this as a limitation in the way organic chemistry was taught in 1927; and his analysis is still valid [7].

> …before the year is up [the student] gets the impression that organic chemistry is a mass of facts [and] forgets much of the first part of the course before [completing] the last part....There is ordinarily a tendency to include too much material rather than too little. The student will learn and remember more if what is presented is sufficiently limited so that [the student] is not completely overwhelmed by it. In the elementary course there is always the question as to what subjects or details are of such importance that they must be included, and what should be omitted to make room for something else.

Authors have also suggested that organic chemistry provides instructors with the advantage of introducing students to the understanding of an authentic subdiscipline. Whether it was Degering, in 1938 [8], or Smith, in 1967 [9], chemists have described imaginative instruction resulting from the organizational interplay between specific yet representative cases and a few yet broadly applicable general concepts that is characteristic of organic chemistry. In 1939, Brewster argued this point strongly [10]:

> 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 [11]:

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

An introductory program based on organic chemistry was introduced at Brown University in the 1940s, as described by Leallyn Clapp in 1976 [12], and the program introduced in the 1950s at Bucknell University continues today [13, 14]. In recent years, perhaps fulfilling Wakeham’s prophecy, many schools have reduced their general chemistry programs to a single term and begin their organic chemistry instruction in the second term of the first year program [15].

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Discussions of the introductory college chemistry curriculum inevitably raise the issue of the high school program (for example, the earlier quote from Wakeham). Abrahams, in 1947, advocated an actual high school course in organic chemistry [16]:

> Vast and complex as the field of organic chemistry may be, its fundamental and underlying concepts are to a large extent beautifully simple and easily comprehensible to secondary-school students.

Reasons for why even incorporation of organic chemistry topics is problematic were provided in two separate replies to Abrahams. The first set of caveats, constructed by Clapp in 1955 [17], included:

1. The high school to college duplication is shifted to a more advanced level.
2. There is an additional expense for the laboratory.
3. There will be a lack of quantitative work.
4. There is an increased danger from fire.
5. There are no suitable texts and manuals.
6. The teachers are not qualified to teach the subject.
7. The subject is too narrow an area for an introductory course.

In 1963, Laughlin reported the results of a survey that reiterated some of the issues raised by Clapp and included the customary “not enough time” [18].

1. There is not enough time to include an extensive new topic.
2. There is a lack of necessary tools and materials.
3. The teachers are inexperienced with teaching the subject.
4. The teachers do not have any background in the subject.
5. Both the ability and the interest of the students in this subject is limited.

On November 4, 1996, the American Chemical Society devoted its annual Satellite Television Series on “Teaching Chemistry” to “Teaching Organic Chemistry in the Introductory Course” [19]. One of the four speakers, Steven Long (Roger Adams High School in Arkansas), discussed the integration of organic chemistry topics in the American Chemical Society’s *Chemistry in the Community* (*ChemCom*) program. The

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other three speakers (Susan Piepho, Sweet Briar College; Slayton Evans, University of North Carolina; and this author) addressed the topic from the college and university perspectives. A report on this seminar will appear in an upcoming *Progress in Practice*.

### Organic Chemistry in Introductory Chemistry Instruction: A Historical Inevitability?

The Industrial Revolution and the rise of the engineering disciplines had a profound influence on introductory chemistry instruction. In less than 20 years, chemical engineering emerged from false starts and the general perception of being oxymoronic (is it chemistry or is it engineering?) to the beginnings of its preeminence in professional training [20]. Chemical engineering programs that were strongly tied to fundamental chemistry instruction set the earliest national standards. One of the most chemistry-oriented programs in chemical engineering was developed at the author's institution when the chemistry faculty at The University of Michigan objected to new (1895) guidelines in the College of Literature, Sciences and the Arts (L.S.&A.) that forbade both structured curricula of required courses and undergraduate degrees identified by their specific discipline (e.g., a B.S. degree in chemistry as opposed to simply a B.S. degree) [21]. By 1898, these chemists bundled their hierarchical course structure together with a few introductory engineering courses and, through the College of Engineering, conferred the first bachelor's degree in chemical engineering. No undergraduate chemistry degree was offered from 1895 until 1914, when the chemists returned to the College of L.S.&A. along with the specifically named B.S. Chemistry degree, which is still offered today.

The practical significance of classical thermodynamics, the practical needs of the engineering clientele, and the development of electronic models of matter combined to transform first-year training in descriptive chemistry into the contemporary general chemistry course, dominated as it is by traditional physical chemistry topics. Although introductory chemistry instruction is always changing, does this change represent progress (or even evolution) if the questions raised in the 1920s are no more easily answered in the 1990s? The strategies for general chemistry instruction have varied but the substance has remained reasonably unaffected. Recent efforts include: (a) creating supplements for the existing general chemistry syllabus, such as the *Materials Science Companion* [22]; (b) preparing thematic "modules" around socially or scientifically relevant topics, such as environmental issues [23. 24]; (c) new and imaginative

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nonmajors courses such as *Chemistry in Context* from the American Chemical Society; and (d) a newly proposed entry (also by the ACS, and announced at the November 4, 1996 Satellite Symposium) into the majors' course that still seeks to anchor itself to the traditional topics in a biological context. A question raised by the Whitmore Symposium, updated by 50 years, remains unanswered: *Is a physical chemistry context still the best choice for introductory college instruction in the 1990s?*

The look of introductory chemistry today might 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. Is there a later historical context in which the question of involving organic chemistry makes sense? 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 beginnings of the *Molecular Structural Revolution* could be assigned to the 1950s, including the development of X-ray crystallography, applied nuclear magnetic resonance spectroscopy, and the proposition for double-helical DNA. During this time, organic chemistry was transformed by the work of the physical organic chemists. Stereochemistry and conformational analysis became immediately integrated into the operations of the science as well as into introductory instruction [25]. What was once a seemingly endless array of empirical relationships coalesced around surprisingly few mechanistic principles. When we hear about the excitement generated by molecular biology and materials science, it is really the richness of structure–reactivity relationships that has 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, and much more so than with the Molecular Structural Revolution, where a substantial reply has not yet happened after nearly 50 years. Were these former changes any less dramatic or putatively more 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

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aggregates, and understanding of the basis of molecular recognition. Does general chemistry provide the only entry into these topics?

## Conclusion

The subject matter of organic chemistry is a mature body of knowledge where the state-of-the-art is nonetheless accessible to introductory instruction. This has only become clearer in the 70 years since the issues were raised, in print, in the proceedings of the Whitmore symposium. The descriptive, pictorial and narrative nature of this subject can create an instructional advantage compared with subject areas where an understanding of post-calculus mathematics is crucial to teaching a contemporary perspective. Unlike typical survey courses, the subject matter of contemporary organic chemistry provides a chance to demonstrate how to construct understanding and operate within a truly hierarchical structure of knowledge.

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