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Of Special Interest

Report On "Comprehensive Curricular Change at a Small Liberal Arts College: Bioorganic First at Juniata College"

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The chemistry faculty were faced with the task of constructing a chemistry curriculum that served the needs of the wide range of students….

Because the conceptual basis of the curriculum is that the majority of the students are not chemists, participants in this session examined which aspects of organic chemistry are really necessary for a nonchemical (mostly biological) audience. Participants learned about Juniata's solution to this curriculum problem and considered whether any of the ideas are useful in other settings. An important consideration is whether the curriculum is indivisible or whether certain parts can be

"Comprehensive Curricular Change at a Small Liberal Arts College: Bioorganic First at Juniata College" by David Reingold 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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adopted without others. Particular examples from the Juniata curriculum were described.

Descriptive Outline:

David Reingold began the discussion by outlining the format of his presentation. A prepared 45-minute formal lecture describing the introductory chemistry curriculum at Juniata College was followed by an open discussion about perceived advantages and disadvantages of the material presented in the lecture. The presenter asked the participants to introduce themselves to the group, stating that for most of the workshop the participants would be discussing curriculum issues amongst themselves. Each participant was asked to give their name, academic affiliation, and field of specialization. The presenter noted that about 75% of the participants were organic chemists, which was also his field of specialization.

The presentation began with Dr. Reingold describing the Chemistry department at Juniata College. Juniata College is a small, isolated college in rural Pennsylvania that has an enrollment of approximately 1,100 students. Unlike at Hereford College, where he taught for one year, if a topic is not covered by your department, you cannot travel a short distance to another institution to find that information. This forces the chemistry department at Juniata (and others like it) to be self-contained; they do cover a wide range of chemistry issues, and they do it in-house. The chemistry department is fairly small. There are six chemistry faculty members, which does not allow for anything other than a single curriculum track. They must create a curriculum that works for all students; they cannot run a general chemistry course for chemistry students and another course for premedical students. The chemistry faculty were faced with the task of constructing a chemistry curriculum that served the needs of the wide range of students enrolled in chemistry courses at Juniata. This curriculum must also be agreed upon by the faculty members tasked with teaching the curriculum. The process for building a new chemistry curriculum began in 1990, with discussions surrounding this topic lasting well into 1993.

Near the beginning of the discussion of the curriculum, the faculty at Juniata were aware of the national debate regarding growing dissatisfaction with the traditional general chemistry course. The chemistry faculty agreed that there were many

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shortcomings in the traditional curriculum. The presenter presumed the reason that the participants were attending this particular workshop was not only a shared interest in general chemistry curriculum reform but also a recognition of these same shortcomings in their own general chemistry curriculum.

Dr. Reingold gave examples of difficulties they had encountered with the traditional general chemistry curriculum at Juniata. The Freshmen students arrive with various levels of chemical education and, when the instructor makes an assumption about what concepts to cover in the general chemistry course, the material presented will most likely be too advanced for several students while being too elementary for others. This difficulty can be found in most any introductory course, but the problem is particularly evident in traditional general chemistry courses because the material is reflective of what the student was exposed to in high school. This raises the next problem concerning the teaching of general chemistry, namely that the students think they have seen this material before. Many of the students have been exposed to several of the concepts but could not grasp the material, and some students have learned how to numerically get the correct answer but have not learned how to approach the conceptual problem. This allows the students to believe they have seen the material before and that they can approach the new material using familiar methods that do not allow them to reach the level of understanding that the instructors are trying to achieve. The mathematics that are involved in freshman chemistry, although not particularly difficult, stretch the ability of some of the students. All colleges attract students with different educational backgrounds, and while this specific problem may not occur in all colleges, experience and hundreds of anecdotal conversations suggest that mathematics is a problem in general chemistry for a majority of colleges. The mathematics required in a typical general chemistry course is sufficiently complex to cause many of the students to concentrate simply on understanding the answer to a chemical problem by focusing entirely on the mathematical method at the expense of comprehending the underlying chemical concepts. Another one of the bigger problems with the traditional general chemistry curriculum is that it is appears very disjointed to the students. While faculty and upper level students may be able with hindsight to see the inherent connections between the various topics covered in general chemistry, the students typically digest the material as “gas law this week,” and “kinetics next week.” While this may not be a general problem, at Juniata the students have difficulty balancing equations using typical chemical symbols (CO_2, H_2O, etc.) before they

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understand that the symbols stand for molecules. Analogies to help the students make this connection (cooking, building bicycles, etc.) do not seem to work because the chemical symbols are not seen as objects. The students are manipulating symbols and nothing more.

About the time the faculty at Juniata were having these discussions, Dr. Seyhan N. Ege and her colleagues at the University of Michigan, along with several other groups around the nation, began to publicize a new method of teaching organic chemistry in the first year of college. The faculty of Juniata became intrigued with this idea and began to identify the advantages and disadvantages of this idea as it related to their search for a reformed general chemistry curriculum. These are summarized below.

Advantages:

- The course material holds together and builds on itself much better than in the traditional general chemistry course.
- A qualitative approach with organic material can give the students a conceptual feel for chemistry.
- Presenting organic content allows the students to take freshman math courses before general chemistry courses. This allows them to tackle the mathematical general chemistry problems with much more confidence. (The merits of this method is not always observed.)
- Students rarely have been exposed to organic chemistry in high school, allowing them all to enter the class with basically the same background (as opposed to the various general chemistry backgrounds mentioned earlier).
- Topics presented in a typical general chemistry course are not presented in context. If the same concepts are taught after being exposed to organic chemistry, the students will have the benefit of applying the concepts learned as they are being presented instead of having to wait for several months for an application.

Disadvantages:

- Most of the students that have to take organic chemistry are not “chemists”. This makes several of the subject matter topics covered in organic chemistry applicable to only a fraction of the students in the class. On the other hand, the minority of

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students, those who are studying to be chemists, need that material because they will not get it in any other course.

- Subject matter that a majority of the students need (i.e., biochemistry topics, because of their interest in the biological sciences) are usually found in the last third of the organic chemistry text and often are not covered in a first-year organic chemistry course.

In order to solve these problems at Juniata, a decision was made to invent a course that was appropriate for the majority of the students in the course. The decision was to teach bioorganic chemistry first, which catered to the 80% of the enrolled students who were going on to study biology. This course would leave out any organic chemistry topic that was irrelevant to the targeted students. Once the decision was made to change the introductory chemistry course, the previous departmental course structure also had to be revised. The project is a work in progress. The current (May 1997) graduating class has "suffered" through an experimental course for the first four semesters of their schooling (most physical and analytical chemistry classes remained unchanged) and some of the faculty are concerned about whether the students have had a better education or not having endured the "growing pains" inherent in inventing a new curriculum structure.

The New Curriculum Structure at Juniata

First-Year Courses

Bioorganic Chemistry—"Organic Chemical Concepts". This course is taught to incoming first-year students. It is a year-long course that meets twice a week for 11/2-hour sessions; it also includes an additional one-hour discussion section (20–25 students). This is a large lecture course (150 students). The assumption is made that the students learned no chemistry in high school. The first six weeks of class are spent teaching the basics of general chemistry (atoms, molecules, etc.) in a biological context. The prerequisite for this class is high school chemistry or instructor permission.

Introductory Biology/Chemistry Laboratory. This class is taught jointly with the biology department (two chemistry professors and two biology professors) and covers the material common to the introductory chemistry and biology class. This is a year-

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long course that meets two afternoons (from 1:00–5:00 p.m.) per week. The students are split into six groups. They are presented four modules (experimental stations) per semester and stay with each experiment for two weeks. The students are given one week after each experiment to analyze the experimental information and write a laboratory report. Each experimental station houses an experiment that has both chemical and biological applications. Some experiments have a decidedly chemical feel while others have a larger biological portion.

Sophomore Courses

Fall Semester: a rigorous analytical chemistry lecture and laboratory course. This course allows a much deeper coverage of analytical chemistry than would be presented in a traditional general chemistry course. A good mathematics background as well as a limited background in chemical properties are assumed. The course meets for three hours of lecture and two afternoons of laboratory each week.

Spring Semester. Students are separated into different sections based on their majors, and two course options are provided: Bioinorganic chemistry and inorganic chemistry. Typically, most of the biologists choose the bioinorganic course while the chemistry students take the inorganic course. In reality these courses have quite similar content, and only substantially differ in content during the last 4–5 weeks. Basically, the material in an advanced general chemistry text is covered at a very sophisticated level. One of these two courses is required for both biology and chemistry majors. There is also a synthesis laboratory for chemistry majors given in parallel with the spring semester inorganic chemistry course. This course is a high-level synthesis laboratory that relies heavily on student research of the literature and relatively little “cookbook” instruction.

Junior Courses

Intermediate Organic Chemistry—“Organic Reactions”. This course is required for all chemistry majors and is a specialized course that is only taken by chemistry majors. One of the standard sophomore organic texts is used and compressed into a one semester lecture course instead of the usual year-long course. This allows the instructor to fill in the blanks of understanding and expand the knowledge base acquired during the freshmen organic class. The biology students are no longer in the chemistry curriculum, which allows the instructor to present the difficult organic concepts that are useful to chemistry majors.

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Senior Courses

Although not yet developed, Juniata would like to offer a "freshmen chemistry" course for seniors. The theory behind this course is that the basic principles that any good chemist should know are all described in a good freshmen chemistry text. If a class can be designed that takes seniors through the text, and discusses the concepts at a highly sophisticated level, then the students will have a much better grasp of the connectivity between chemical concepts. The students would leave the course with a solid knowledge of chemical principles. Several other more traditional senior-level courses are also required during a chemistry major's senior year.

These courses summarize the thoughts behind the changes in the curriculum at Juniata College. How did the changes affect the students? Can any increase in chemistry comprehension and retention be observed? These questions cannot be answered yet with certainty, but several trends after the implementation in the 1993–94 school year can been related. The initial implementation of the new curriculum was difficult, and the first year was not very positive. The first graduation class that used the new curriculum graduated in May 1997. The faculty wanted a way to gauge whether or not the new curriculum was having any effect on student learning. Data were collected during the last years of the old (standard) general chemistry curriculum at Juniata in preparation of implementing the new, bioorganic-first curriculum. In order to have a fair comparison, because the changes occur in the first two years of the chemistry curriculum, the chemistry faculty began to administer the American Chemical Society General Chemistry examination to the junior chemistry majors. The results were quite surprising. Although the students had been receiving chemistry instruction for two years at the college level, the chemistry majors could do no better that an average in the 65th percentile on the freshman-level ACS general chemistry examination.

The Fall 1995 data are not too surprising because the students who took the exam in the fall of 1995 were subjected to experimental classes that had never been attempted before and (admittedly) had several flaws. The second group through the new curriculum (Fall 1996) scored noticeably higher on the ACS examination. Whether or not the increase can be attributed to the new curriculum or to improvements in the new courses made between the first and second year of implementation was not clear to the Juniata faculty. It could also be attributed to several external variables (smarter students, smaller chemistry major enrollment, etc.). Whatever the cause for the apparent increase in scores, the faculty were encouraged by the fact that the change in

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TABLE 1. Average Percentiles for the Freshmen ACS Examination given during the Junior Year to Chemistry Majors at Juniata College.

Year	Average	Curriculum
Fall 1992	64.0	old
Fall 1993	n/a	
Fall 1994	63.4	old
Fall 1995	63.1	new
Fall 1996	79.9	new

TABLE 2. Average Percentiles for the GRE Chemistry Practice Examination Given during the Senior Year to Chemistry Majors at Juniata College.

Year	Number of Participants	Average	Curriculum
Fall 1992	9	38.3	old
Fall 1993	n/a		
Fall 1994	14	44.4	old
Fall 1995	4	33.0	new
Spring 1996	11	56.0	new

curriculum had not forced a downturn in examination scores. A participant observed that the scores, even in Fall 1995, were looking better than years past; the 1995 scores were really being dragged down by two very low scores. The presenter hesitated to agree because of the qualitative nature of the data evaluation.

Chemistry majors were given a practice GRE examination during their senior year as another benchmark to evaluate the impact of the new curriculum. The impetus for administering this examination was two-fold: first, to give the students an idea of where they stood before taking the actual GRE and second, to examine any impact of the new curriculum.

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The latest examination could not be given in the fall term, and the participants were cautioned that the 1996 numbers were not collected under the same conditions as the prior years, which could explain much of the increase in the 1996 scores. While no tangible increase in the scores was attributed to the new curriculum, the upward trend, when coupled with the ACS scores, was encouraging to the Juniata chemistry faculty. Participants asked questions regarding other changes in departmental policy that could be attributed to the increase in scores. While there had been some recruiting changes at Juniata, the number of chemistry majors had remained relatively constant (at 10–20 students per year). No other major change in the chemistry department had been found to account for this trend.

The presenter moved the discussion towards the chemical content of the first year bioorganic course. A handout indicating the concepts that were added and omitted from the course was discussed. It was mentioned that all of the omitted material is presented to the chemistry majors in the junior-level organic course.

This was the end of the formal presentation.

Discussion

Questions

1. How were the Physical chemistry courses effected by the changes made to the first and second year courses?

After you eliminate the traditional general chemistry course and replace it with a course that is mostly organic, the second year courses must also radically change. Once that second year is finished, however, you have covered basically the same material as you would have in a traditional curriculum. This means that most of the upper-level courses could stay intact and that is what happened in the case at Juniata. The physical chemistry Juniata faculty member had a gut feeling that the students were doing better under the new curriculum because their math is stronger by the time the get the “general chemistry” material and that helps when they get to the physical chemistry courses.

2. How do the physical chemists feel about teaching the new bioorganic first year course?

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The don't have to teach it. The chemistry faculty at Juniata is comprised of two organic chemists, one physical chemist, one inorganic chemist, one analytical chemist, and one biochemist. Only the organic chemists teach the introductory course. In the large introductory course, however, there is the primary lecturer teaching the class and two other chemistry faculty members who sit in on the lectures and conduct two of the smaller discussion sections each. They do not participate in giving the large lectures.

3. Do you have any results on how the biology majors did on the MCAT? Any increase with the new curriculum?

No data was taken. The first year the course was taught, the course was set up quite differently then what has been presented. The other organic faculty member took nearly nine weeks to cover the general chemistry portion of the class. When they got to the MCAT, the students felt underprepared for the organic portion of the exam. The MCAT has started to include less and less actual organic chemistry content. In terms of getting students into medical school, there has been as much success with the new curriculum as in the past. As far as graduate school goes, the first batch will be starting this year and it will be interesting to track their progress. As far as being accepted to graduate school they have been just as successful as in the past.

4. What has the student response been to the new curriculum?

The biology students have always hated organic chemistry and they still do. Although the biology faculty have been invited to sit in on the new chemistry curriculum developments in hopes of having them build on what we are attempting, this has not happened. Chemistry faculty have sat in on the biology courses that follow our chemistry course, and discussions between chemistry and biology faculty have been constant. Unfortunately, members of the biology department have not elected to sit in on the new chemistry curriculum and have not integrated their program with chemistry's. The interdepartmental connections have not been as strong as they should have been.

5. Is there anything particularly inherent to organic chemistry that makes it easier to teach as a freshmen course?

There is nothing about organic chemistry that makes it better or worse to teach to freshmen; however, teaching the general concepts of chemistry in a context (whether it

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be organic, bioorganic, inorganic, etc.) is much easier that the traditional method. In the bioorganic first class, several of the students cruised through the first part of the class (the general chemistry section) on the strength of their high school chemistry. When the course shifted to the organic portion, the grade distribution shifted dramatically. One of the challenges is to convince the students to recognize that they have to shift gears when they hit the new (organic) material. Telling the students that this is going to happen is just not good enough. If the student does not have to work hard during the first six weeks when the organic material is started they seem to inevitably fall behind.

Some of the participants raised the issue that the inherent differences in student population can contribute greatly to this difficulty of motivating the students. There will always be a distribution of talents and personality. Some students learn visually, some mathematically, and some students will excel in general chemistry topics while others will find the organic subject matter easier. The presenter brought the conversation back to the importance of having a context in which to present the general chemistry material. There were several contexts that could work, and at Juniata the suitable context is organic, given the make up of the faculty. The important issue is that you have a context for the material, whatever that context may be.

Discussion continued on the question of how students learn. The fact that students enjoy learning subjects that connect with their particular talents was discussed. Some students like chemistry because of a mathematical aspect while another larger group enjoy chemistry because of a visual aspect. Catering to both groups is a constant challenge for an instructor. Some participants felt that some aspects of organic chemistry were much more conceptual and visual giving the students that had a talent for visualizing complex molecular reactions an inherent advantage over the students that had more of a mathematical talent. It was observed that many placement examinations for chemistry in several different colleges were based mostly on mathematics. The scores on these mathematical examinations is a good indicator of how the students would perform in a traditional general chemistry course, but a very poor indicator on how they would perform later in the more conceptual chemistry courses. Some of the students who do poorly on the mathematics placement examination end up struggling through general chemistry, but they really enjoy and excel in organic chemistry. Are we somehow penalizing these visual students with these math-oriented exams? One of the participants identified that in the text used for

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the bioorganic course, the biological aspects of the course were still listed last. It seemed as if the first-year course might not be a bioorganic course at all, but just a "watered-down" organic course.

Questions

1. How was the biological aspects of organic chemistry incorporated into the course?

These aspects appear after the organic aspects of the course are presented, typically when the students have enough information to discuss a biological example of an organic chemistry concept. Many other schools have tried to teach organic first; however, they have essentially tried to just teach the traditional organic chemistry class during the first year using a traditional organic chemistry text. This is not the intent in the Juniata program. The aim here is trying to teach the topics typically covered in a general chemistry course within a bioorganic structure; it is rather difficult to find a suitable textbook for this purpose.

2. What about the politics of changing the teaching of general chemistry? Typically, physical and analytical faculty in off semesters end up teaching general chemistry. If you change the general chemistry course into a bioorganic course, what happens to the faculty that used to teach the general chemistry course?

This is part of the difficulty Michigan had with the implementation of its particular organic chemistry curriculum. At Juniata, we never really encountered this problem because we have a relative abundance of organic faculty, so this strategy worked. This will be a problem for departments that have a number of faculty that have become "specialists" in general chemistry instruction. What do you do with these faculty if you make such a change? There are several institutions that have a chemistry for nonmajors course, for example, so that is one place they could go. It's a problem.

The discussion ended with the majority of the participants agreeing that changes to the traditional general chemistry curriculum at most institutions must be forthcoming and that the changes implemented at Juniata solved a problem particular to their specific needs quite well.

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