“Less is More:” The 1:2:1 Curriculum at Indiana University

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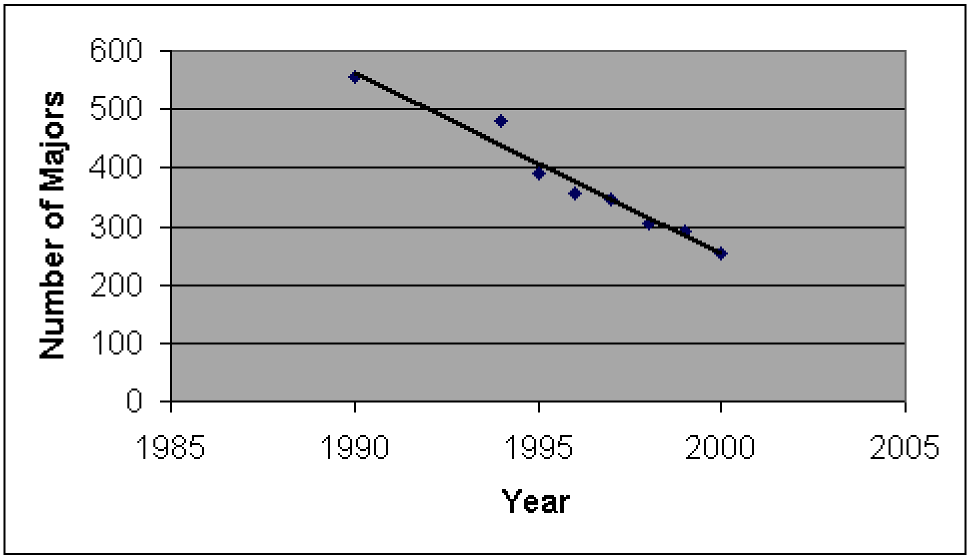
Abstract

Indiana University (IU) has recently undertaken a curriculum reform project in order to modernize the program and recruit students into the chemistry major. As part of this reform, we chose to adopt a 1:2:1; General, Organic, and Intermediate Inorganic sequence in order to create a fast-track to higher level courses. In this model, “less” General Chemistry is required in the beginning, but a “more” interesting and advanced Intermediate Inorganic course follows the Organic sequence. A one semester, 5-credit *integrated* laboratory-lecture course in General Chemistry has been developed in order to prepare students for direct entry into the Organic sequence. The course deviates from the order of most traditional chemistry texts in that an “Atoms First” approach is utilized. Organic and biochemical examples are emphasized and laboratory experiments are closely correlated with concepts from the lecture portion of the course. The reasons for curriculum reform, contents of the course, details of implementation, and assessment of student retention and recruiting will be discussed. Student performance in Organic Chemistry and topics covered in the 4th semester intermediate Inorganic course will also be presented.

Introduction

Indiana University (IU) Department of Chemistry recently adopted a new sequence of freshmen-sophomore level courses as part of a broad curriculum reform project to revitalize the chemistry major. This sequence, commonly referred to as 1:2:1, consists of one semester of General, two semesters of Organic, and one semester of Intermediate Inorganic. The curriculum reform project began in response to a drastic decline in the number of chemistry majors at IU that occurred during the 1990's. In the early 90's, IU had nearly 550 chemistry majors and ranked near the top of all universities in the number of majors produced. As shown in Figure 1, the number of majors steadily declined from approximately 550 to 250 over the course of 10 years. By extrapolating the trend line, the number of chemistry majors would approach *zero* by 2007! Of course chemistry majors would never cease to exist, but the curriculum committee decided that action must be taken to reverse this trend. This decline in majors at IU was particularly disturbing because it appeared to be specific to our campus and not indicative of a national trend. The National Center for Education Statistics reported that during the 1990's the number of chemistry majors awarded in the U.S. increased steadily from 8,311 in the 1990-1191 school year to 9,989 in 1999-2000 (http://nces.ed.gov/programs/digest/d04/tables/dt04_290.asp).

Figure 1: Number of students majoring in Chemistry and Biochemistry at Indiana University during the 1990's. The data from the year's 2001-2006 will be presented later in the paper to demonstrate the effects of curriculum reform on the number of majors.



Upon some investigation it was discovered that other scientific disciplines at IU were not losing majors in a trend similar to chemistry and, in contrast, the total number of biology majors had increased dramatically. From this information, it was inferred that the many students interested in the life sciences perceived biology to be a more relevant major and chose it instead of chemistry. The curriculum committee decided to examine the unique student population at IU, the content of individual chemistry courses, and the requirements for the chemistry major to identify key changes that would attract strong students and revitalize the program. As a result of this curriculum committee's investigation the following general recommendations were made for reform.

- **Demonstrate relevance of chemistry to the life sciences.**

The science students at IU (and many other universities) are particularly interested in the life sciences. At IU, an exceptionally large fraction of science students pursue majors and careers in the life sciences because our campus does not offer engineering programs. In order to relate chemistry to students' interests, biological examples should be incorporated in introductory classes and Biochemistry courses should be made available earlier in the curriculum. In the old sequence of courses prerequisite requirements prohibited students, including biochemistry majors, from taking even a single biochemistry course until the end of their junior year. If students can see how chemistry is directly related to important problems in the life sciences they will be more likely to continue their studies in this field.

- **Make the major flexible and customizable** .

In order to meet the needs of all different kinds of students from those who aspire to work as a B.S. chemist in industry, to medical school bound, to graduate school bound, the chemistry major should be flexible. Students should be able to customize their major and take upper level courses in their area of interest. In order to meet this goal, some classes must be dropped from our current major requirements and additional advanced courses in each division should be offered.

- **Reform General Chemistry**

General chemistry has been taught in the same way for decades. Is this the best method for teaching introductory material and does it inspire students to continue their studies in this field? In order to address this question a diverse committee consisting of new and experienced faculty from all divisions of chemistry was formed to examine the content of general chemistry and make recommendations for improvements.

The 1:2:1 Curriculum as a Solution

A 1:2:1 curriculum was adopted as a means of achieving the curriculum reform goals outlined above. As mentioned earlier, the majority of students enrolled in chemistry courses at IU are pursuing life sciences related majors. The introduction of organic chemistry in the first year has several benefits for these students. The early introduction of organic coordinates better with biology curriculums that are becoming more molecular in nature. Connections between chemistry and biological systems are more easily made and student interest in chemistry is often increased with exposure to organic chemistry. This model is also ideal for creating a faster track to Biochemistry courses and upper level courses in general. This is because organic II is often prerequisite for these courses and it is now taken in the third semester as opposed to the traditional sequence where it is taken in the fourth semester. If the relevance of chemistry to the life sciences is demonstrated early it is more likely that students will choose to continue their studies in this field.

The 1:2:1 curriculum in combination with IU's revised major requirements offer the advantage of a more flexible and customized major. In our new model, required courses can be completed by the junior year thus allowing a student to customize their senior year with chemistry lecture and laboratory electives that suit their interests. Table 1 shows the courses which are required for an ACS certified B.S. Chemistry and Biochemistry Degree at IU. This figure also depicts a sequence map or the recommended sequence of chemistry courses. The recommended sequence of courses from other disciplines is also included to illustrate the overall course load for the semester. Note the earlier access to upper level courses and the flexibility in the senior year. By the fourth semester B.S. Chemistry majors can be enrolled in Analytical Chemistry and the newly created Intermediate Inorganic course which is more life science focused due to the inclusion of bio-inorganic topics. In the fourth semester of the B.S. Biochemistry major, students can be enrolled in Bioanalytical chemistry and Biochemistry. This new curriculum model can spark student interest by allowing early access to upper level courses that demonstrate the relevance of chemistry in solving real world problems. In addition, the major requirements in the senior year consist entirely of chemistry lecture and lab electives. Students must take 6 credits of advanced lecture electives and 4 credits of advanced lab electives to meet the requirements for the major. In this curriculum model, all divisions of chemistry offer advanced lecture and lab courses that serve as electives for students. Examples of advanced lecture course electives are Inorganic Chemistry, Physical Biochemistry, Nuclear Chemistry, Environmental Chemistry, Biological Chemistry, and Computational Chemistry/Molecular Modeling. Examples of advanced lab course electives are Biochemistry, Electronics, Bioanalytical Chemistry, Inorganic Chemistry, and Advanced Synthesis.

Table 1: Sequence Map for B.S. Chemistry and Biochemistry Degree at IU

The sequence map illustrates one recommended pathway for meeting degree requirements, but alternative pathways exist.

B.S. Chemistry Degree

Semester 1 (16 cr.) English Composition (3 cr.) **General Chemistry I Lecture/Lab (5 cr.)** Calculus I (4 cr.) Foreign Language (4 cr.)	**Semester 2 (15 – 17 cr.)** Topics Course (COAS-E 103/104) (3 cr.) **Organic Chemistry I (3 cr.)** Calculus II (4 cr.) Foreign Language (4 cr.) Elective (1 – 3 cr.)
Semester 3 (16 – 17 cr.) **Organic Chemistry II (3 cr.)** **Organic Lab (2 cr.)** Physics I (5 cr.) MATH: Calc III/Linear Algebra/Diff Eq (3 – 4 cr.) Foreign Language (3 cr.)	**Semester 4 (17 cr.)** **Intermediate Inorganic Lecture/Lab (5 cr.)** **Analytical Chem. Lecture (4 cr.)** Physics II (5 cr.) Biological Mechanisms (3 cr.)
Semester 5 (15 – 17 cr.) **Analytical Chem. Lab (2 cr.)** **Physical Chem. I (3 cr)** **One Semester Biochemistry (3 cr.)**	**Semester 6 (15 – 17 cr.)** **Physical Chem. II (3 cr.)** **Physical Chem. Lab (2 cr.)** Intensive Writing (3 cr.)

Distribution (A&H or S&H) (3 cr.) Elective (4 – 5 cr.)	Electives (7 – 9 cr.)
Semester 7 (15 – 17 cr.) **CHEM lecture elective (3 cr.)** **CHEM lab elective (2 cr.)** Distribution (A&H or S&H) (3 cr.) Electives (7 – 9 cr.)	**Semester 8 (15 – 17 cr.)** **CHEM lecture elective (3 cr.)** **CHEM lab elective (2 cr.)** Distribution (A&H or S&H) (3 cr.) Electives (7 – 9 cr.)

B.S. Biochemistry Degree

Semester 1 (16 cr.) English Composition (3 cr.) **General Chemistry I Lecture/Lab (5 cr.)** Calculus I (4 cr.) Foreign Language (4 cr.)	**Semester 2 (17 cr.)** Topics Course (COAS-E 103/104) (3 cr.) **Organic Chemistry I (3 cr.)** Calculus II (4 cr.) Biological Mechanisms (3 cr) Foreign Language (4 cr.)
Semester 3 (16 cr.) **Organic Chemistry II (3 cr.)** **Organic Chemistry Lab (2 cr.)** Physics I (5 cr.) Molecular Biology (3 cr.) Foreign Language (3 cr.)	**Semester 4 (15 cr.)** **Biochemistry I (3 cr.)** **Bioanalytical Lecture/Lab (4 cr.)** Physics II (5 cr.) Distribution (A&H or S&H) (3 cr.)
Semester 5 (15 – 17 cr.) **Biochemistry II (3 cr.)** **Physical Chem. I (3 cr.)** **Intermediate Inorganic (5 cr.)** Intensive Writing (3 cr.) Electives (1 – 3 cr.)	**Semester 6 (15 – 17 cr.)** **Biochemistry Lab (2 cr.)** **Phys. Biochem. or Physical Chem. II (3 cr.)** Distribution (A&H or S&H) (3 cr.) Elective (4 - 6 cr.)
Semester 7 (15 – 17 cr.) **CHEM lab elective (2 cr.)** **CHEM lecture elective (3 cr.)** Distribution (A&H or S&H) (3 cr.) Electives (3 – 5 cr.)	**Semester 8 (15 – 17 cr.)** **CHEM lecture elective (3 cr.)** **CHEM lab elective (2 cr.)** Approved BIOL course (3 – 5 cr.) Distribution (A&H or S&H) (3 cr.) Electives (5 – 7 cr.)

First Semester General Chemistry Course

Another goal of curriculum reform was to analyze the content of the General Chemistry course and make recommendations for improvement. The 1:2:1 sequence set up a unique situation for General Chemistry reform because an entirely new class would be created. A one semester General Chemistry course has advantages to the student from a pedagogical standpoint. Topics such as covalent bonding, resonance, molecular structure, and polarity from a traditional first semester course directly apply to organic chemistry. It is likely that the coverage of topics from a traditional second semester general chemistry course that do not directly relate to organic such as nuclear chemistry or descriptive inorganic can detract from what students know and remember.

In an effort to create the best one semester General Chemistry course, a diverse committee consisting of faculty from all divisions of chemistry was formed to make suggestions for course content. Faculty members representing each division were included so topics essential for upper level courses in each area were not omitted. Faculty members with significant experience teaching General Chemistry were included because they were familiar with the level of detail of the topics and student capabilities. In addition, faculty members with no General Chemistry teaching experience were included to provide a non-biased fresh look at the course. This group of faculty analyzed the current General Chemistry syllabus and many General Chemistry and Introductory Chemistry texts and after much discussion came to some consensus.

The committee's suggestions resulted in a 5 credit combined lecture and lab course which contains three lectures, one lab lecture, one recitation, and one laboratory period each week. The topics in the first semester General Chemistry course should focus entirely on concepts that are essential to the next course in the curriculum, Organic Chemistry. The committee also agreed that the ordering of topics in the majority of General Chemistry texts came across and random and disjointed to the students. The committee preferred a nanoscale to macroscale approach that many introductory chemistry texts follow. In this approach, often referred to as “Atoms First,” a storyline of atoms to molecules to chemical reactions is developed throughout the semester. First the composition of the atom and its periodic properties are described, then bonding theories are introduced, and once molecules are formed their properties are explored. Finally chemical reactions and their fundamental properties such as thermodynamics, kinetics, and equilibrium are described. Table 2 outlines the topics and the amount of time dedicated to each in the newly created one semester General Chemistry course.

Table 2: List of Topics in First Semester General Chemistry Course

Topic	**Number of 50 minute lectures**
Atomic Structure - Nucleus - Electronic Structure - Periodic Trends	5
Ionic Bonding -Formulas, Naming, and Properties	1
Covalent Bonding -Lewis structures -Resonance -Formal Charge	4
Molecular Structure - Geometries (VSEPR Theory) - Hybridization	2
Bonding Theories -Valence Bond Theory - Basic MO Theory	3
Polarity and Non-covalent interactions	3
Phases of Matter - Properties of Gases, Liquids, and Solids - Gas Laws	3
Energy Changes: Thermochemistry - Definition of heat, work, energy, and enthalpy - Calorimetry: Measuring energy and enthalpy changes - Calculating enthalpy changes using thermodynamic data - Energy of Phase Changes	7
Kinetics -Reaction rate and order -Integrated rate laws -Factors affecting reaction rate	6

-Reaction mechanisms -Catalysis	
Equilibrium - Equilibrium Constant - Equilibrium Calculations - Le Chatelier's Principle	5
Thermodynamics - Reactant and Product Favored Processes - Entropy - Gibbs Free Energy	6

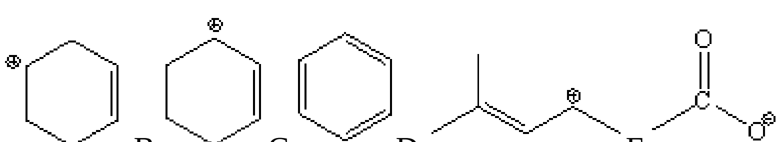
Note that the first 5 chapters of most traditional General Chemistry texts which includes topics such as stoichiometry, naming of compounds, and types of reactions are omitted from the lecture syllabus. These topics were omitted because they were deemed to be repetitive and uninspiring for students who have a reasonable background from a high school chemistry course. These topics are not going to provide students with any insight into the modern world of chemistry nor inspire them to study chemistry further. Instead the course starts with a modern and challenging introduction to atomic structure. Students learn about the composition of the atom in more detail than in previous high school courses. This topic also is ideal for describing sophisticated instrumental techniques such as mass spectrometry and scanning tunneling microscopy as they relate to these topics. The goal is to immediately provide students with an insight into the world of the modern and exciting research.

Although these introductory topics are omitted from lecture, students are still held responsible for the material. A chemistry placement exam is required for any student enrolling in the course and if they do not demonstrate proficiency in these skills they are required to take an introductory chemistry course. In a typical semester at IU, 250 students take the introductory course while 500 students score well enough on the placement exam to directly enter the first semester of the 1:2:1 curriculum. Also, these introductory topics from chapters 1-5 are reviewed throughout the semester. During the first week of classes an online assignment and recitation sections are dedicated to reviewing these skills. In addition, stoichiometry, measurement, and naming of compounds are emphasized heavily in the laboratory portion of the course.

Another difference between our one semester General Chemistry course and the material covered in many traditional General Chemistry texts is the enhanced focus on organic and biological molecules. The focus of this course is not to introduce organic chemistry by having students memorize items such as functional groups or how to name compounds, rather organic examples will be applied to General chemistry concepts throughout. Organic examples are utilized in the topics of Lewis structures, resonance, formal charge, geometry, polarity, and non-covalent interactions because during committee discussions it was noted by the Organic faculty that students had very little understanding of how to apply these concepts to organic molecules and why these concepts are important in determining reactive sites. In an effort to bridge the gap between General Chemistry and Organic Chemistry, organic examples are introduced heavily in these topics. Figure 2 shows example test questions that illustrate how organic chemistry is incorporated into these General Chemistry topics.

Figure 2: Examples of General Chemistry Test Questions Incorporating Organic Chemistry

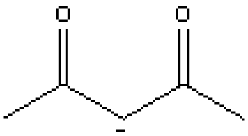
Example 1: Which of the following does **NOT** exhibit resonance?



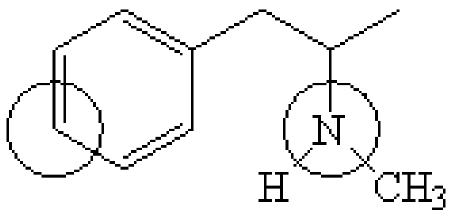
A. B. C. D. E.

Example 2: a) Fill in all hydrogen atoms and lone pairs in the anion below. The negative sign indicates formal charge on the carbon.

b) Provide two better resonance structures for the anion, using curved arrows to show how you have moved electrons from one structure to another.



Example 3: Methamphetamine is a highly addictive drug that has been demonstrated to cause irreversible brain damage.

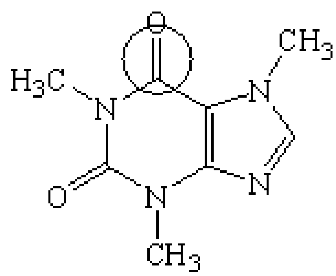


methamphetamine

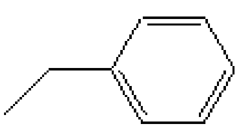
a) Determine the molecular formula of methamphetamine.

b) Determine the molecular shape, hybridization, and bond angles around the circled nitrogen and carbon.

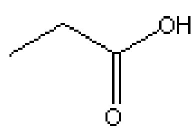
Example 4: In the following molecule, caffeine, determine the correct **ORBITAL OVERLAP** description for the circled bond.



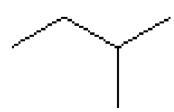
Example 5: Which of the following amino acid side chains would be considered **hydrophobic** ?



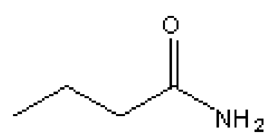
Phenylalanine



Aspartic Acid



Leucine

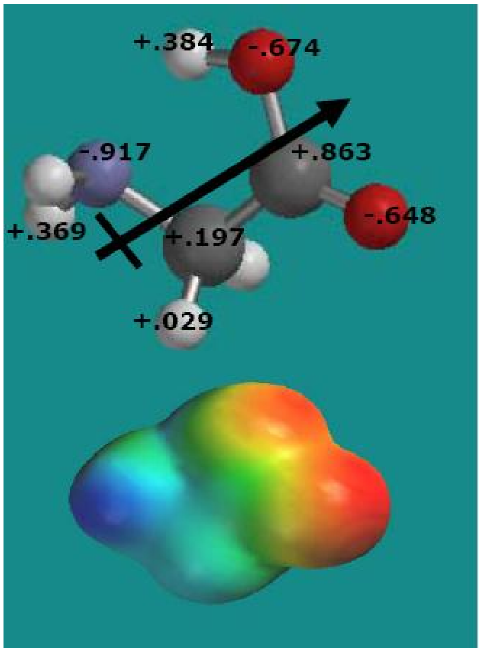


Asparagine

Another goal for the one semester General Chemistry course was to correlate lab experiments with lecture topics to reinforce understanding of concepts by providing hands-on experience exploring chemical principles. Although there are many laboratory experiments that address topics such as atomic structure, thermochemistry, kinetics, equilibrium and thermodynamics, it is difficult to devise experiments that cover the topics of bonding, molecular structure and intermolecular forces. Therefore, several new “dry” labs that utilize molecular model sets and molecular modeling programs were incorporated. The first lab is a discovery based exercise in which students use VSEPR theory and Styrofoam balls and toothpicks to create models of molecules and deduce bond angles. This lab precedes the coverage of VSEPR in the lecture so students are really “discovering” the bond angles by building models and trial and error. Molecular model sets are then used to build organic molecules such as butane or aspirin to visualize how VSEPR translates into 3 dimensional shape of larger molecules. Students learn how to draw projection formulas to represent 3 dimensional shape and learn how rotation around a bond changes the shape of the molecule. In a computer based molecular modeling lab, Spartan is utilized to refine concepts from the VSEPR lab. Students explore trends in bond length, the effects of lone pairs on bond angles, and the effects of resonance on bond length. The polarity of different molecules can be compared by calculating and visualizing dipole moments and electrostatic potential maps are utilized to show how charge distribution within molecules affects reactivity and intermolecular forces. Figure 3 shows an example of these calculations in the glycine molecule. The importance of shape and intermolecular forces in biological binding events is also illustrated with this program using several examples. The student response to these labs, especially the molecular modeling lab has been amazingly positive. Student comments indicate that visualizing molecular shape and properties on the computer has been extremely helpful to them in understanding and retaining these concepts.

Figure 3: Molecular Modeling Calculations on the Glycine Molecule Using Spartan

Students draw the glycine molecule in Spartan and measure optimum bond angles and bond lengths. They are asked to discuss the effects of lone pairs and size of atoms on molecular shape, bond angles and bond lengths. They calculate partial negative and positive charges on atoms and draw an electrostatic potential map illustrating regions of positive and negative charge. From these calculations they are asked to determine reactive sites (nucleophilic and electrophilic) and discuss acid-base concepts.



Modifications in the Teaching of Upper Level Courses

Another factor to consider in the adoption of the 1:2:1 sequence is the impact of the course changes in other areas of the curriculum. One primary concern was that important topics that are no longer covered in General Chemistry will be lost from the curriculum. Topics from a traditional two semester General Chemistry course that are **not** covered in the new one semester General Chemistry course are acid-base chemistry, complex equilibria, buffers, electrochemistry, nuclear chemistry, descriptive inorganic, and transition metal coordination chemistry. The strategy in ensuring coverage of these topics is to include them in upper level courses where they are directly relevant. For example, acid-base chemistry is now covered qualitatively and quantitatively in Organic Chemistry I. In addition to teaching how structure affects the acid-base properties of organic molecules, quantitative acid-base calculations are also described. According to a current Organic I professor, six lectures are now dedicated to this topic as opposed to the three lectures used in the past. Topics such as nuclear, redox, and coordination chemistry are now covered in the Intermediate Inorganic course and a more detailed description of this course is provided later in this paper. Buffers are now covered in Biochemistry, and aspects of electrochemistry and complex equilibria are covered in Analytical Chemistry.

Another concern that arose in the early phases of implementation of the new curriculum was that freshmen students with less maturity and college experience would slow the Organic class down and not allow the typical amount of material to be covered. To alleviate these concerns, spectroscopy topics such as IR, Mass Spectrometry, and NMR are now covered in laboratory where they are most directly relevant. However, after two semesters of teaching Organic chemistry with students from the new one semester General Chemistry course, it was discovered that the same amount of material as pre-curriculum reform can be covered.

Content of Intermediate Inorganic Course

In our 1:2:1 curriculum model the fourth semester course is Intermediate Inorganic. The goal of this 5 credit lecture-laboratory course is to provide a more rigorous and biologically relevant class than the traditional second semester of General Chemistry. Although some topics from the General Chemistry sequence such as redox and nuclear chemistry will be covered, the focus will be on the structure and bonding of inorganic compounds. Transition metal coordination compounds, organometallic compounds, and bioinorganic complexes can be covered in significantly more depth because students will be familiar with bonding concepts from organic chemistry. The Intermediate Inorganic course is being taught for the first time in the Spring of 2007 at Indiana University. The required text for the course is Inorganic Chemistry, 2 nd Ed. , by Catherine E. Housecroft and Alan G. Sharpe. Table 3 shows a detailed outline of the topics covered. Higher level inorganic laboratory experiments include Synthesis of Zeolite A, Synthesis and Characterization of a Vitamin B 12 Model System, Preparation of a Silicone Polymer, and Synthesis, Purification, and Characterization of Copper (II) Tetraphenylporphyrinate (CuTPP).

Table 3: Topics in the 4th Semester Intermediate Inorganic
*Note: The course is in its first iteration and this list of topics may change as the course evolves.
Nuclear Chemistry Nuclear Binding Energy Radioactivity Artificial Isotopes Applications of Isotopes Fission Multinuclear NMR spectroscopy in inorganic chem. Mossbauer spectroscopy
Reduction and Oxidation (Redox) Oxidation States Standard Reduction Potentials Standard Reduction Potentials and Relationships between E°, ΔG° and K Disproportionation reactions Potential Diagrams Applications of Redox Reactions
Introduction to Molecular Symmetry Symmetry operations and symmetry elements Point Groups Character tables Why do we need to recognize symmetry elements?
d- block Chemistry Electron Configurations and Physical Properties Characteristic Properties (Color, paramagnetism, complex formation, variable Oxidation states) Electroneutrality Principle Coordination Numbers Isomerism

d-block Chemistry: Coordination Complexes High and Low Spin Valence Bond Theory Crystal Field Theory Molecular Orbital Theory Ligand Field Theory Electronic Spectra and Magnetic Properties Thermodynamic Aspects: Ligand Field Stabilization Energies
d-block metal complexes: reaction mechanisms Ligand Substitutions Substitution in Square Planar Complexes Substitution and Racemization in Octahedral Complexes Electron-transfer processes
d-block metal complexes: reaction mechanisms Ligand Substitutions Substitution in Square Planar Complexes Substitution and Racemization in Octahedral Complexes
Homogeneous and Heterogeneous Catalysis Basic Concepts of Catalysis Homogeneous Catalysis and Applications Heterogeneous Catalysis and Applications
The trace metals of life Metal Storage and Transport: Fe, Cu, Zn, V Dealing with O 2 Biological Redox Processes The Zn 2+ ion: Nature's Lewis Acid
Organometallic Chemistry

Assessment of New Curriculum

How are students performing in the new one semester General Chemistry course?

The new one semester General Chemistry course can be considered more rigorous than the first course in the two semester sequence because introductory topics such as stoichiometry and nomenclature are not covered in detail and several more advanced second semester topics (kinetics, equilibrium, and thermodynamics) have been added. Therefore, the number of failing grades (D's and F's) as well as the number of students who have withdrawn (W) from the course were tracked and compared to previous semesters. This (DFW) data is also used to assess the effectiveness of the placement process for the course, which consists of a chemistry placement exam and a sufficient score on the SAT/ACT math component. At IU, in the years 1996-1998, a placement process was not utilized and all students who wished to enroll in General Chemistry were allowed to do so. The average DFW rate for this time period was 31.7%. In the time period 1999-2002, the placement process was used to select students for General Chemistry in a traditional 2 semester sequence. The average DFW rate for this time period dropped to 25.2%. After the new one semester General Chemistry course was implemented in 2003 and the same placement criteria was applied, the DFW rate dropped to be consistently near 15% each semester. These results show that the placement exam has been effective in increasing student retention and potential for success in General Chemistry. In addition, the new one semester General Chemistry course is not too rigorous for the students because a greater percentage of students are completing the course with a passing grade.

Another way to evaluate student performance is to compare mastery of chemical concepts from students in the new curriculum with those in the old two semester sequence. However, this assessment was difficult to perform quantitatively because the content of the General Chemistry class changed dramatically and a standardized test was not administered to both sets of students. Each semester the professor of the course prepares his/her own exams and thus semester to semester comparisons are difficult. Qualitatively, instructors indicate that they are covering the material in the same depth as before and feel that students are mastering the material at the same level or higher than they have in the previous traditional two semester sequence. One topic that was examined more quantitatively was students' knowledge of stoichiometry. Much less lecture time was dedicated to this topic in the new curriculum and several faculty members voiced concern that students would be greatly deficient in their understanding of this topic. In order to assess student understanding of stoichiometry, questions covering this topic were included on each exam. It was found that students performed very well on these questions, and typically approximately 75% of the class could answer the question correctly. Therefore, we concluded that less emphasis on this topic was not negatively affecting students' ability to answer these types of questions.

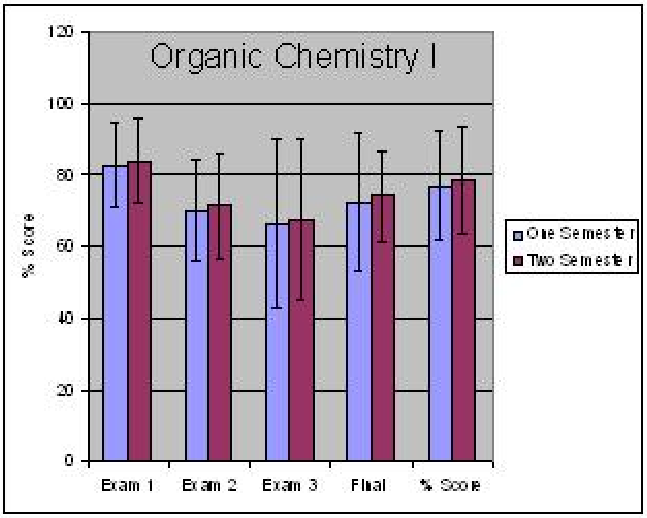
How are students performing in Organic chemistry?

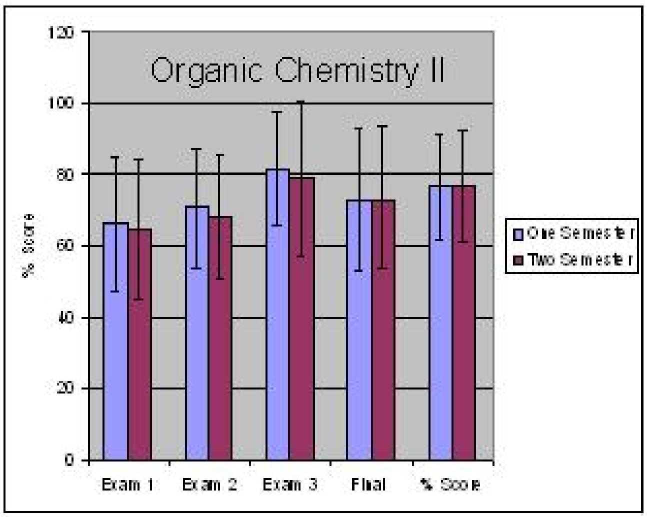
Another aspect of the new curriculum that was examined was student performance in Organic chemistry. In the Spring of 2006, a large number of students entered Organic Chemistry directly after the new one semester General Chemistry course. This semester provided an excellent opportunity to evaluate student performance in Organic in the new curriculum because there was also a large of number of students who had followed the traditional two semester General Chemistry sequence. Figure 4 shows the average scores on Organic Chemistry I and II exams of students who had taken the one semester General Chemistry course only and of students who had taken two semesters in a traditional General Chemistry sequence. In Organic I, the students from the old two semester curriculum consistently performed *slightly* better. On each exam their average was about 1 to 1.5 % points higher than students in the new curriculum. However, upon following the same set of students through Organic II the trend reversed. The one semester General Chemistry students consistently performed about 1 to 2 % points higher on exams than students who had taken two semesters of General Chemistry. In addition, the final letter grade distribution for both sets of students in each class were compared and found to be very similar. From this data, it can be concluded that students who have taken only one semester of General Chemistry perform essentially the same in the Organic Chemistry sequence as those who have taken the two semester General Chemistry sequence.

However, we predicted that students in the new curriculum would have performed better in the Organic I due to the focus on preparation for the course in General Chemistry. Upon examining the materials used in the new General Chemistry course for this set of students it was found that emphasis on organic examples was moderate. Therefore, the next time the class was taught a faculty member with extensive experience teaching Organic developed many more homework problems dealing with bonding, resonance, formal charge, geometry, and hybridization in organic molecules. Evaluation of student performance in Organic after the incorporation of these new problems will be examined in the future. Another possible explanation of the slightly worse performance in Organic I by the one semester students is that these students had less college experience in general.

Figure 4: Comparison of Student Performance on Exams in Organic Chemistry I and II.

“One Semester” students took the new one semester General Chemistry course in the Fall of 2005 and “Two Semester” students took the second semester of a traditional General Chemistry sequence in the Fall of 2005. The average score and the standard deviation is displayed.



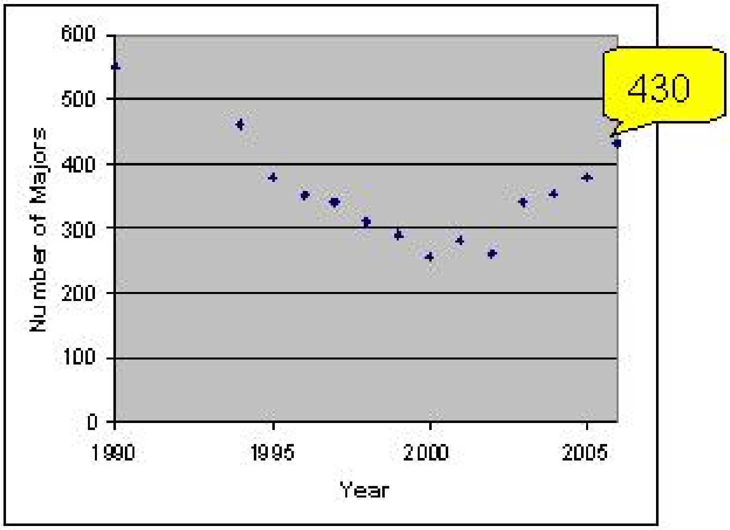


Has Curriculum Reform Recruited More Chemistry Majors?

One of the main goals of curriculum reform was to demonstrate the relevance of chemistry to the future careers of many students and to recruit more good students into the chemistry major. The 1:2:1 Curriculum reform project was implemented in the Fall of 2003 and Figure 3 shows the effects of this change on the number of Chemistry and Biochemistry majors at IU. Once curriculum change was implemented, the trend of declining majors was reversed and by 2006 the number of majors had grown by 180 students to reach 430 total! It is impossible to directly link the increasing number of majors to curriculum reform but the drastic increase in majors is most likely a result of the changes made. The students enrolled in chemistry classes at IU were informed of these changes and our goals for curriculum reform by holding mass meetings with the chemistry advisor and publishing information in our undergraduate newsletter which is circulated to all students enrolled in chemistry classes. The increased number of majors might also be attributed to the fact that the students are aware that the department is striving to create a modern educational environment that best suits their needs.

In addition to implementation of the 1:2:1 Curriculum, other small changes were made in our undergraduate program to better serve the needs of the students. For example, large General Chemistry classes now utilize clickers to promote active participation by the students and feature careers in chemistry by bringing in working chemists as guest speakers. A series of one credit professional courses that help students refine their skills in giving presentations and provide information about professional schools and careers have been added to chemistry course offerings. Also, the department now holds an internal graduation ceremony each Spring where each student receives recognition for his/her personal achievements. These changes may also have had some effect in recruiting students to become chemistry majors.

Figure 5: Number of Chemistry and Biochemistry Majors at Indiana University .



Conclusion

The chemistry department at Indiana University has instituted a 1:2:1 sequence as part of a broad curriculum reform project with excellent success. This curriculum has been a means for our department to emphasize the relevance of chemistry to the life sciences by enabling the early introduction of organic and biochemistry courses. Likewise, this sequence has created flexibility in course requirements whereby majors can select more chemistry lab and lecture electives that suit their interests. A new one semester General Chemistry course aimed at preparing students for direct entry into Organic Chemistry was created and this course, in combination with a placement process, has resulted in increased student retention and success. Students in the new General Chemistry curriculum go on to Organic Chemistry and perform equally as well as students who have previously had two semesters of General Chemistry. Even though students in the new curriculum are performing well in Organic chemistry, changes are still being implemented in order to provide the most effective one semester General Chemistry course possible. A new fourth semester Intermediate Inorganic Course incorporating pre-requisite knowledge of organic chemistry will investigate inorganic chemistry with respect to the life sciences, and it will be taught for the first time in the Spring of 2007. The success of the curriculum reform project can be demonstrated by the dramatic increase in the number of chemistry majors that occurred since changes were made. In addition, many students and faculty have expressed satisfaction with the new courses and curriculum. For example, many students have mentioned that early introduction of organic and biochemistry has helped them grasp connections between biology and chemistry, and the current Organic professor has noticed that students come to the course with a much better understanding of prerequisite concepts. Among the many student comments we receive, this one exemplifies our more recent responses: “I found the classes at IU to be very informative and well structured. I didn't think that it was possible to actually understand, let alone enjoy, organic chemistry. I feel my gen chem class really prepared me for organic. I received a B in your class (organic), and I am more proud of that B than any other grade. I can honestly walk away and say that I learned more in organic than any other class at IU.” This student switched from a biology major to a chemistry major that same semester. These types of comments are in stark contrast to the comments we have received in the recent past regarding chemistry classes. Overall, our curriculum overhaul was time intensive endeavor that proved to be well worth the effort.

Note: More information about our curriculum and courses can be found on the IU Chemistry Department Undergraduate web page.

http://www.chem.indiana.edu/academics/ugrad/

The one semester General Chemistry course number is C117, the Organic lecture and lab courses are C341, C342, C343, and the Intermediate Inorganic course in N330. More detailed information about course content or materials can be obtained by e mailing requests to Jill Robinson (jirobins@indiana.edu)

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CONFCHEM on-line conferences are organized by the ACS Division of Chemical Education's Committee on Computers in Chemical Education (**CCCE**). Send additions or corrections for this page to John H. Penn at John.Penn@mail.wvu.edu