UNIVERSIDAD NACIONAL AUTONOMA DE MEXICO

PROVIDING OUR HETEROGENEOUS STUDENT BODY WITH A LAUNCHING PLATFORM TO SUCCESSFULLY PURSUE CHEMISTRY CAREERS

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(*Moderator's note:* There has been a student-led strike at UNAM for the past 5 months. The strike has shut down the school and the faculty, including the authors of this paper, have not been able to work since the strike started. I am very grateful that they have written this contribution to ConfChem '99. The normal e-mail addresses, which route through UNAM, are not reliable at this time. The lead author, Carlos Castro-Acuna, has an alternative address at which he can be reached more reliably; castroacuna02@yahoo.com Once again, my thanks on behalf of the ConfChem '99 staff, Don Rosenthal and Brian Tissue, for this contribution. - Paul Kelter)

Prelude

We are teachers involved with the first-courses in the first semesters of every career included in the Chemistry School at Universidad Nacional Autonoma de México (UNAM), the largest university in Mexico, with a student population of over 270,000. These careers are Chemical Engineering, Metallurgical Chemical Engineering, Chemistry, Pharmacy-Biology-Chemistry and Food Technology.

Contrary to the situation generally occurring in the United States, the students in the first-year General Chemistry Course intend on having a Chemistry-related career, so at this level, we do not have to deal with a curriculum suitable for other fields like Medicine or Biology. Our main objective is to cover contents that we consider to be fundamental for any student to successfully conclude his or her courses in the Chemistry school. Our main obstacle is the heterogeneous background of our students. In this paper we will comment on how we teach them basic skills along with covering the main chemistry concepts that they should have acquired in their previous secondary and high school courses (but they commonly have not).

Introduction

The main objective of the General Chemistry course at the UNAM Chemistry School is to provide the students with a framework of knowledge and abilities that we consider indispensable for their future success. Among these abilities are:

Management of information - How to obtain important data from the different available sources;

Experimental planning - How to design an experiment in accordance with a well-established hypothesis.

Reasoning - How to extract logical conclusions from experimental or theoretical data

Report preparation - How to prepare a written report (with proper spelling too !)

Students entering our General Chemistry course have a heterogeneous background, not just in Chemistry but also in other important areas such as mathematics and physics . At UNAM, we receive youngsters coming from families of diverse socioeconomic levels and this often results in students who have poor reading and writing skills. In most Mexican states, after one or two years of Kindergarten, at age 6, children enter the primary school (six years) and then continue with three more years of secondary school. Just recently, the Mexican Government made it mandatory for every child to receive nine years of "basic education" which integrates the primary and the secondary school curricula.

After this basic period, students can continue their education in many different "scholar systems", some leading to technical options and others designed to prepare the youngsters for University careers. The students who enroll at UNAM's Chemistry School come mainly from three different systems: Escuela Nacional Preparatoria (National Preparatory School); Colegio de Ciencias y Humanidades (Science and Humanities School), and; Colegio de Bachilleres (Bachelor's College - high school-level) For simplicity, and considering that the Chemistry topics are similar in these systems, from now on we will call this level "Preparatory " (quite similar to U.S.High School) . Here is the curriculum that prepares students for the preparatory course.

Chemistry at the secondary school

Following the Natural Science course received in the primary school, Mexican students will study chemistry topics in the three years of the secondary school in the following manner :

1st Year, (7th grade in the USA) Introduction to Physics and Chemistry **- Mostly phenomenological and with the main objective of familiarize the students with the concepts of analysis and observation of natural phenomena.**

2nd year. Chemistry 1. **- At this level is already possible to find a ChemCom influence. Although many chemistry topics such as atoms, subatomic particles and chemical reactions are introduced, the main idea is to show the benefits that this science has brought for the humankind and to "convince" the kids that their chemistry knowledge will be useful to better understand Mexico's natural resources, with the hope of finding solutions to possible pollution problems in their own communities. A special emphasis is given to the presence of chemical products in our homes, from natural ones like sugar and vinegar to manmade plastics, detergents and paints, pointing out how these materials improve our quality of life. Considering the importance of oil production in our country, many references will be made to the many products that we can obtain with petroleum refining. (See Table 1).**

3rd year : Chemistry 2. – Keeping the Science-Technology-Social mainframe**: in this course students are supposed to learn more about basic nomenclature, balancing chemical equations, concentration units, and functional groups in organic chemistry. It is interesting that one-third of this course is dedicated to electrochemistry, a very important area that will not receive very much attention in the next courses. Similar to the previous course, many references are made to establish a good relationship between Chemistry and the Environment. Topics like acid rain, water and soil pollution, ozone and air pollution are well-covered.** *In all three secondary courses the main idea is to present Chemistry as the Hero, not the villain .*

Table 1. Main concepts covered in the secondary school courses Chemistry 1 and Chemistry 2.

Chemistry 1	Chemistry 2
1.1 Chemistry and you . Chemical processes in living forms. Chemical substances in our blood. Everyday events: a match burning, a fried egg. Law of conservation of mass. Natural and synthetic products. Oil refining and it's principal derivatives. 1.2 States of matter. Solids, liquids and gases. Phase transformations. Heterogeneous and homogeneous mixtures. Solutions, colloids, solubility and separation methods. 1.3 History of the atom. Dalton model . Avogadro's number and the concept of mole. Periodicity, families. Names and symbols of the main elements. Metals and No-Metals , chemical bond.	2.1 Water. Its natural cycle and the importance for our lives. Aqueous solutions, molar concentration, parts per million. Electrolytic dissociation, cations and anions. Acids, bases and neutralization. Medical use of Antacids. 2.2 Oxidation, reduction, combustion. Oxygen properties and reactions. Corrosion. Fuels and other products obtained by oil refining. Organic compounds. Nitrogen and sulfur oxides, acid rain. 2.3 Electrochemistry. Electrical conductivity. Redox processes. Metal electrorefining. Electrolysis. Batteries and accumulators.

This curriculum is very ambitious. We would be very happy if the students entering our General Chemistry course had really this knowledge background. However, our diagnostic tests show that, commonly, students will lose more than gain Chemistry knowledge in the next three years.

Chemistry at the preparatory school

As we mentioned above, one of our main concerns is to recover the chemistry knowledge that our incoming students should have but for many reasons lack. This obligates us to be very attentive to any changes produced at the high school

level .

In 1996, the junior year high school general chemistry course in Mexico was redesigned by the High School General Administration (Dirección General del Bachillerato), largely as a result of influence from American programs such as Chem Com and Chemistry in Context. This new course is surely more attractive for the *general* student body but it provides less basic chemistry to those that intend to follow scientific careers. This situation manifests itself in the organization of the Chemistry Olympiads; those students attending these "light" chemistry courses will need more time to acquire a competitive level.

At this point we want to compare the former and the new Mexican high school general chemistry course curricula, to outline the main differences between the two, and to make a preliminary evaluation of potential effects of this change on college-level chemical education.

The traditional general chemistry course systematically covered the main unit areas of chemistry. The topics it covered were, in the following order: *ponderal laws* (a newly-used term that incorporates the Law of Conservation of Mass, the Law of Constant Proportions and the Law of Multiple Proportions), atomic nature and structure, properties of the different states of matter, descriptive periodic inorganic chemistry, nomenclature, the use of mathematical equations to represent chemical reactions, and stoichiometry. It was very broad and overly optimistic, and as a result it displayed high student failure rates

As we just mentioned, the new course design is strongly influenced by programs such as Chem Com, which in previous years have changed chemical education in other countries. The main objective of these programs has been to place chemistry in the context of broader economic, ecological, and social realities and to make it more appealing to students.

Because the majority of high school students the general chemistry course will have this as their last exposure to scientific education, the committee designing the new course decided to shift away from a "hard" science approach and towards a "softer" one that underlines the effects of science and technology on everyday life and broader economic and social issues. Additionally, this is expected to make the course more interesting to students who will not pursue science or engineering degrees.

Accordingly, the resulting course attempts to ensure that students acquire a basic science culture and a set of skills that will allow them to :

Develop their critical analytic skills.
Broaden their knowledge base.
Improve their oral and written communication skills, and
Develop a critical conscience regarding the impact of science and technology.

The new course is organized around the following five thematic units: energy, water, air, soil, and chemistry in development. The following concepts are covered across the thematic units with varying degrees of depth:

behavior of matter
concepts of mixture
compounds and elements
chemical reactions
chemical bond theories
structure of matter
periodic classification of elements
applications of chemistry.

A more detailed curriculum is presented in Table 2.

Table 2. Main concepts covered in the former and the current first (junior) course of Chemistry at Escuela Nacional Preparatoria. (120 hours total, four hours a week)

NEW PROGRAM	FORMER PROGRAM
UNIT I . ENERGY, MATTER AND CHANGE.	**UNIT I. INTRODUCTION TO GENERAL CHEMISTRY**
What is energy ? **Matter and changes** **The Sun, a nuclear reactor** **Man and its energy demands.**	**What is Chemistry ?** **Chemistry and other Sciences** **Importance of Chemistry as an experimental science** **Mass and Energy conservation laws.**
UNIT II. AIR, UNTOUCHABLE BUT VITAL.	**UNIT II.-PONDERAL LAWS**
What is the air ? **Air composition; reactivity of its components.** **Air quality**	**Importance of ponderal laws in chemical changes.** **Chemical formulas** **Qualitative and quantitative relationships**

	in chemical processes.
UNIT III. WATER , FROM WHERE ? FOR WHAT?PROPERTIES?	UNIT III.- THE ATOM . ITS NATURE AND QUANTUM STRUCTURE
A lot of water, but we can die because much of it is not drinkable Importance of water for the humankind Why is water so marvelous ?	Subatomic particles: electron,proton and neutron. Atomic number, atomic mass, isotopes . Quantum numbers. Quantum model for the atom. Electronic configuration.
UNIT IV. THE EARTH CRUST. A SOURCE OF USEFUL MATERIAL FOR THE MAN. Minerals, a civilization milestone? Oil, a matter and energy treasure. Soil, our food support. Conservation or annihilation of our Planet.	UNIT IV.-PERIODICITY. CHEMICAL BONDS . Importance of periodicity Moseley Law Characteristics of periodical classification Types of chemical bonds. Lewis structures.
UNIT V. FOOD, FUEL FOR LIFE. Essential chemical elements for life. Sources of energy and body materials. Food conservation.	UNIT V.-NOMENCLATURE AND CHEMICAL REACTIONS Symbols and oxidation numbers of most common elements. Oxides, acids, bases and salts. Molecular and structural formulas Types of chemical reactions. Balanced equations. Methods for balancing equations. What is chemical equilibrium? Solving stoichiometry problems.

In the new program, chemical concepts are studied through practical issues, but not in a systematic manner. For example, the effect on the atmosphere of sulfur, carbon, and nitrogen oxides is studied, but there is no systematic explanation of the periodic properties of these elements. Another example is the study of specific reactions between water and iron across the different thematic units, but without a systematic explanation of oxidation-reduction nor any other type of reaction.

Another area where the new course departs substantially from the old one is chemical nomenclature. Although nomenclature is considered as the basic language of chemistry, it is not addressed on its own in the new course. Instead, the names and formulas for compounds pop up throughout the thematic units. As a result, students who have completed this course only know the name and formulas for very few compounds.

The following conclusions do not attempt to measure the intrinsic value of the redesigned course. Instead, they attempt to evaluate the course from the vantage point of college chemistry professors and to place it in the context of its linkage with college General Chemistry courses at the UNAM's Chemistry School.

There is some preliminary evidence that the new program may result in some problems because it leaves a gap between the knowledge level currently expected from freshmen pursuing chemistry or chemistry-related majors (such as biology, chemical engineering, or medicine) and the new course's contents. This may mean that a new general chemistry course will have to be introduced at the freshman college level in the different undergraduate science and engineering schools to cover the contents that were dropped from the former high school course.

The former program had seven more units :

UNIT VI.-HYDROGEN, OXYGEN, WATER AND HYDROGEN PEROXIDE.

UNIT VII.-GASEOUS STATE

UNIT VIII.-LIQUID STATE. SOLUTIONS AND COLLOIDS.

UNIT IX.-HALOGENS AND SULFUR

UNIT X.-ELECTROLYTE SOLUTIONS AND ELECTROCHEMISTRY

UNIT XI.-NITROGEN, PHOSPHOROUS, CARBON AND SILICON

UNIT XII.-GENERALITIES ABOUT METALS

The supporters of the new program could argue that a good teacher could manage to cover the same topics just managing to accommodate the information somewhere within the new five units. We consider that a well-designed curriculum is never good by itself; a good teacher will always get better results with a poorly- designed program than a bad teacher with a marvelous curriculum. However we have to accept that many teachers are young , with not enough educational experience and they will use the programs as a basic guideline for their courses. If the programs look "light" the course will very probably be also "light" causing many students to get a lot of nice information but a precious-little good formation and too little basic Chemistry.

A full evaluation of the effects that the new Chemistry program will have on college chemical education will be possible only after the first classes of students that have completed the new courses in high school have entered UNAM (this should happen in August 1999) and also have completed their first semester term in the Chemistry School (theoretically around January 2000 if the current student-based strike that is keeping UNAM closed is finally over). At that point, we will be able to use the results from the entrance and first-term diagnostic examinations to make a more informed evaluation of the new high school first chemistry course.

It is our opinion that high school teachers are starting from a very low knowledge level and not taking advantage of the strong content present in the secondary school Chemistry programs. In their defense we have to recognize that kids seem to have a marvelous capacity to forget whatever they had learned the previous year. Accepting that this course would be insufficient for students seeking to continue a science career , in the last high school year there are additional Chemistry courses. At this point students can choose among four different areas. Table 3 shows the contents of Chemistry courses for areas I and II.

Table 3. Main concepts covered in the Chemistry courses for areas I and II at Escuela Nacional Preparatoria.

CHEMISTRY IV AREA I PHYSICS MATHEMATICS ENGINEERING	CHEMISTRY IV AREA II BIOLOGY AND NATURAL SCIENCES
ENERGY AND CHEMICAL REACTIONS System. State function. First Law of Thermodynamics. Internal energy. Enthalpy. Thermochemistry. Hess Law. Entropy. Free energy . Exothermic and endothermic reactions. Electrochemistry. Corrosion.	VITAL LIQUIDS Water structure. Molar and molal concentrations. Isotonic solutions. Acid-Base theories. Equilibrium constant. Le Chatelier principle. pH. Neutralization, Titration, Buffer systems.
RATE AND EQUILIBRIUM OF CHEMICAL REACTIONS Rate theory. Activation energy. Factors that affect the rate : concentration, temperature, contact area, catalyzers. Chemical Equilibrium. Eq. constant. Le Chatelier principle. pH.	CHEMISTRY TO UNDERSTAND LIFE PROCESSES Electronic energy levels. Electronic configuration. Lewis symbols. electronegativity and bond type. Hydrocarbons: alkanes, alkenes, alkines, aromatics. Functional groups. Organic reactions: Substitution, addition, elimination, condensation, hydrolysis . Oxidation-Reduction. Polymerization.
BASIC ORGANIC CHEMISTRY Electronic energy levels. Electronic configuration. Lewis symbols. electronegativity and bond type. Hydrocarbons: alkanes, alkenes, alkines, aromatics. Functional groups.	ENERGY AND THE LIVING BEINGS First Law of Thermodynamics. Internal energy. Enthalpy. Thermochemistry. Hess Law. Entropy. Free energy . Exothermic and endothermic reactions. Carbohydrates. Lipids. Enzymes, catalyzers. Rate reaction. Aminoacids and proteins.
ORGANIC REACTIONS	

Substitution, addition, elimination, condensation, hydrolysis . Oxidation-Reduction. Polymers.	

Students planning to enroll at UNAM's Chemistry School will usually cover Area II courses. It is interesting to note that in our opinion, those planning to study Chemical Engineering or Metallurgical Chemical Engineering could get a better preparation covering the Area I program.

With these additional courses, students should have a solid footing on which to continue with their college education. Unfortunately in many cases our students have just "passed" without having a "significant learning". In other cases they are coming from other educational systems where they do not receive a good enough formation in chemistry.

In view of this situation, the UNAM Chemistry School has for many years applied a mandatory diagnostic test for all enrolling students (around 1,000) in order to asses their real background in mathematics, physics, chemistry, general knowledge and English. If a student does not get good grades, he or she is advised to take a remedial course that splits the first semester courses in two terms. There is also a program designed for high- achievement students in which they can choose more demanding courses, not based in a different contents but in more demanding teachers.

General Chemistry at UNAM's Chemistry school

The mainstream General Chemistry course has been in place for the last ten years and is common for all careers; it includes five theoretical hours and ten laboratory hours per week. It is usually covered in one semester (around 16 weeks) but as we mentioned before, it is offered in an extended two semester version for those students with serious deficiencies in their previous education. It is still a matter of debate if the University must take care of these ill-prepared students. Some faculty members believe that in order to keep a good level of education we ought to start from a high level and concentrate on just the best students; others consider that Mexico's social conditions impose the obligation for UNAM to provide a good education to all students, even assigning resources to cover their lack of a good previous education. For the last three decades we have been trying to keep a good balance between a high-quality education and our duty to attend more than 270,000 students (although just 5,000 at UNAM's Chemistry School).

The core of this course is stoichiometry, a fundamental topic that every professional needs to understand thoroughly and manage comfortably. The main objective is to provide the student with a correct and homogeneous language and all the most basic chemistry topic including: the correct use and transformation of measure units; nomenclature; periodicity; molecular structure; energetical changes and chemical equilibrium for different types of chemical reactions.

In the ten experimental hours, there has been established a new project called " Reform of the experimental teaching ". The idea is to eliminate the "cookbook" experiments and, rather, confront the student with a "real" problem in which he or she will need to design a strategy and use all his or her experimental skills in order to solve it. For this program, fifteen "most relevant" topics were selected: density, solubility, limiting reactant, ponderal laws, chemical reactions, Avogadro's number, units of concentration and chemical equilibrium. Generally speaking the results are good although many students still fail the course mainly due to their lack of understanding stoichiometry rules. It is our opinion that many students fail not due to finding chemistry difficult but due to their poor mathematical background. In the first rounds of the National Chemistry Olympiads, all problems that require some level of algebra appear to be of high difficulty.

A new proposal

Due to the enormous pressure that the NAFTA agreement is having at all levels, the curriculum for all careers at UNAM's Chemistry School have been subject to radical changes. Our Chemistry curriculum is being redesigned based on programs carried at MIT, UC-Berkeley and CalTech. At least one of us (CMC) believes that these changes are based on the false presumption that a succesful program run in one institution will be automatically successful in another one. At this point we hope that our readers already have a good idea of how different UNAM is from other prestigious USA institutions. This situation makes almost impossible to succeed by just "importing" curriculums without considering the vast socio-economical differences between our two countries.

Four years ago a curriculum revision was in placed in UNAM's Chemistry School. The idea is to have two common semesters for all Chemistry careers. Within this new vision a drastic reduction of credits is being imposed and many hours of experimental teaching at the lab are just going away. The contents actually covered in our General Chemistry Course will be distributed among three independent courses,

COURSE	SEMESTER	THEORY HOURS	LAB HOURS	MAIN CONTENT
BASIC CHEMISTRY I	1	3	4	Stoichiometry
STRUCTURAL CHEMISTRY	1	3	0	Atomic structure and chemical

				bonds.
BÁSIC CHEMISTRY II	2	1	4	Chemical Equilibriium

These introductory courses are supposed to support the next courses like Organic Chemistry, Inorganic Chemistry, Analytical Chemistry and Physical Chemistry. Nobody knows right now if these courses will really promote the significant learning that all our students will need to succeed in their careers. However we can postulate that the reduction of lab hours will not be a good contribution for academic purposes; perhaps it will be useful to reduce costs in an institution where students are not willing to pay for their education.

Another new proposal ?

Following the pattern of NAFTA changes on Mexico's college education, perhaps we will need in the near future a General Chemistry course similar to those existent in the United States. Based on this, we want to finish this contribution with a proposal for a new General Chemistry course that could be used in the first semester of every career, scientific or not. In order to be useful for students with very different interests, a framework is proposed and then the final part of this one-semester course is accomplished with optional topics:

FRAMEWORK

1. **Properties of matter**
2. **Basic aspects of atomic and molecular structure**
3. **Basic nomenclature of organic and inorganic most common compounds.**
4. **Periodicity**
5. **Stoichiometry . Mass conservation law.**
6. **Thermochemistry.**
7. **Chemical Equilibrium.**
8. **Kinetics**

OPTIONAL

Nuclear Chemistry.

Material Science.

Organic Chemistry.

Biochemistry

Electrochemistry. Corrosion.

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