Chemistry Teaching through the Student's World

A High School Project in Mexico

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The first chemistry lecture on the American continent probably was given 200 years ago in *El Real Seminario de Minería* in Mexico City by Fausto de Elhuyar, the eminent Spanish chemist who discovered wolframium in 1783. He used as his textbook the first Spanish translation of Lavoisier's *Traite Elementaire de Chimie* published in the New Spain in 1797. Undoubtedly both Elhuyar lectures and the discovery of vanadium by Andres Manuel del Río in 1801 gave chemistry in Mexico a brilliant and auspicious beginning (*1*).

Now that a Free Trade Agreement has been signed by the governments of Canada, the United States, and Mexico, we have to think not only of the impact it will have on our industries, but also of the strengthening of our educational and social ties. A primary and manifest academic reaction is for each country to learn much more about the others' educational systems. The purpose of this paper is to introduce the reader to an emerging project in high school chemistry learning and teaching in Mexico.

Mexico now can be characterized by social contrast and population growth, as are many other countries in the Third World. There are 81 million people, with a mean per capita income of less than $3000 US dollars. The annual birth rate passed from a maximum of 3.5% in 1970 to about 2% last year. That is why the age distribution shows a plethora of young people. (Half of the population is under 20 years of age.) At present all these teen-agers have started knocking on the doors of secondary and college institutions.

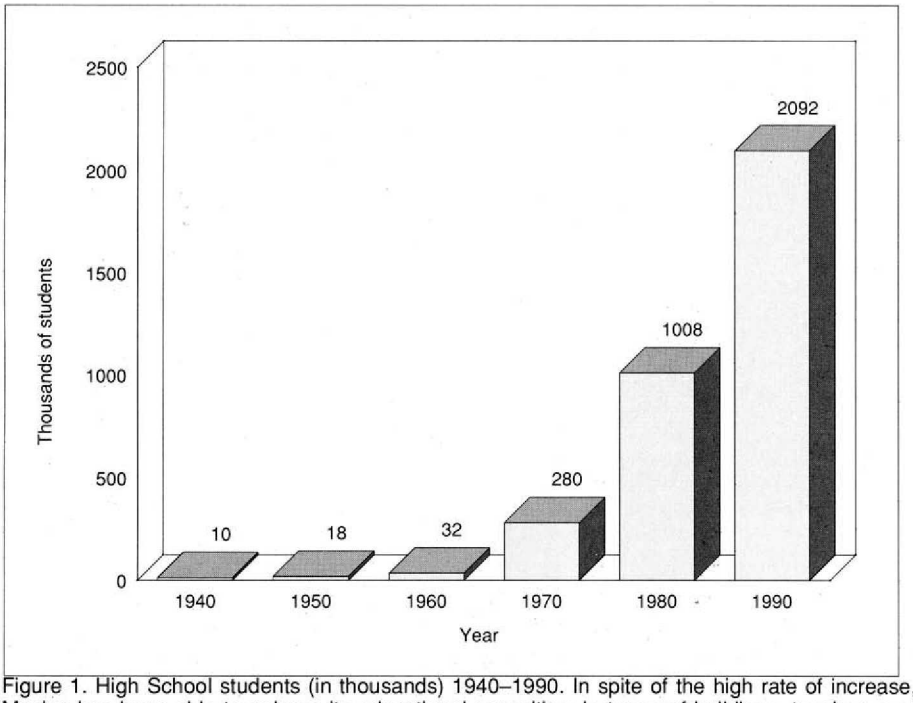

Figure 1. High School students (in thousands) 1940–1990. In spite of the high rate of increase, Mexico has been able to enlarge its educational capacities, in terms of buildings, teachers and resources.

In this paper we will focus on high school education (equivalent to 10th–12th grades in the United States), which has two main objectives in Mexico: to prepare students for undergraduate education and/or to train them for technical jobs.

The growth of the student population in high school is shown graphically in Figure 1. From 1980 to 1990 the proportion of high school students with respect to the population between 15 to 19 years changed from 13.1% to 22.2%. In spite of the enrollment growth, only one out of every four Mexican youngsters can be given an adequate high school education. As a consequence, Mexico faces the formidable problem of training the teachers needed by such an acute educational demand. Admitting even more students, as is desired, necessarily means preparing one more teacher for each 15 new students.

Table 1. A Typical Technological High School Syllabus in Mexico

Fundamentals	General Chemistry	Technological Processes
Matter	Stoichiometry	Chemical industry
Atomic structure	Chemical reactions	Examples of processes
Periodic table	Chemical equilibrium	
Chemical bonding	Chemical kinetics	Ecological and socio-economical implications for Mexican industry
	Inorganic nomenclature	
	Organic functional groups and reactions	

Each column is a one semester course.

The two million high school students are educated by 127,000 teachers, 6,000 of whom are chemistry teachers. There are 5,000 high schools in Mexico, each with an average of 400 students. These schools receive financial support from one of three sources: federal (42.5%), state (41.6%), and private (15.9%).

High School Education and Chemistry Inside It

In spite of the huge high school population increase, the proportion of students that choose to study a professional career related to chemistry decreased from 10% to 5% in the last 20 years. This worldwide phenomenon has worried chemistry teachers and educational authorities. In fact, in Mexico it may affect chemical and petrochemical industries on their way to maturity. It has to be remembered that Mexico maintains the first place in the production of several minerals in the world. Moreover, it is fifth in oil and 12th in petrochemicals productions.

To correct the decreasing trend in the students' selection of one of chemistry carrers as a choice, there is a pressing need for a nationwide effort. The project related with this paper represents an alternative to meet the challenge of recovering the social importance of chemical literacy and improving the teaching and learning of chemistry in Mexico, which was more widespread some years ago.

The number of chemistry courses in high school varies for federal, state, and private systems, from one to four semesters, each one with an average of three to four hours a week. Students oriented to scientific or technological areas receive two additional chemistry courses. Most of the traditional syllabi emphasize the so-called "principles of chemistry", an influence that arrived in Mexico from the international chemical education trends of the 60's, represented by projects as "ChemStudy", "Chemical Bonding Approach" and that of Nuffield Foundation. In Table 1 a typical three-semester curriculum is presented as an example.

With well-grounded hopes, with such a syllabus a good Mexican high school chemistry student would be able to:

- describe the principles of the scientific method,
- identify the diverse manifestations of matter and energy,
- write down the electronic configuration of atoms and minimally predict their physical and chemical properties,
- understand the different models of chemical bonding and its influence on the properties of matter,
- give the names of compounds in a minimal set of inorganic and organic substances,
- write and balance chemical equations and solve stoichiometric problems,
- recognize the states of matter and interpret their behavior through the kinetic molecular model,

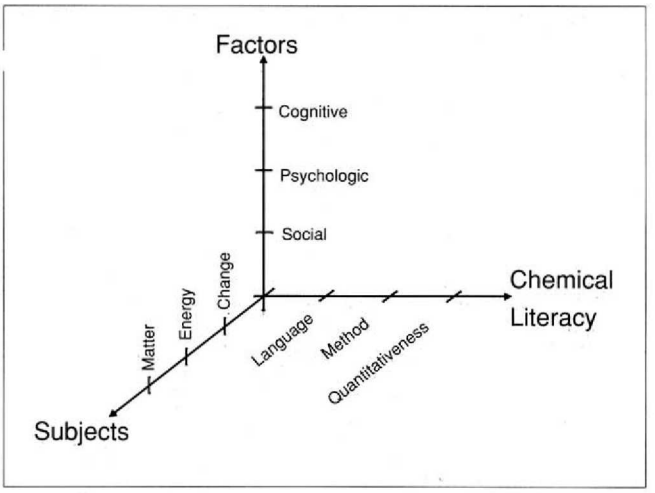

Figure 2. Three dimensions, three subjects, and three elements to acquire chemical literacy.

- know simple theories and reactions of the acid–base and oxidation–reduction types,
- describe the structure and reactivity of simple organic compounds.

This represents an adequate knowledge of chemistry, but do we realize that only 5% of the students will choose a career related to chemistry? Are these capacities needed by the other 95%, that is, by most of our citizens? Do we take enough time to teach the importance of chemistry for society? What do we present concerning the relation of chemistry to clothes, food, transportation, solution to pollution problems, health, energy supply, household products, etc.?

Our impression is that our traditional programs consume too much time to enable students to learn abstract "chemical principles" and relatively too little time to explore the importance of chemistry in everyday life and in the production of goods for our individual and collective necessities.

Meeting the Challenge: Through the Student's World

Mexico has to react to meet the challenges before her. That is why we have developed an alternative of teaching high school chemistry for this decade of the 90's, that (see Fig. 2):

(1) develops the traditional subjects of matter, energy and change,

(2) recognizes pedagogical advances and focuses on the following three factors (2):

- *Cognitive* (this is the minimum body of chemical knowledge needed by students to interpret nature),
- *Social* (the relation to the social situation of today's world and country) and
- *Psychological* (significant chemical knowledge can be achieved only through a psychologically constructed sequence),

(3) and realizes that chemical literacy can be summarized in the management of three main elements (see Table 2 that includes some examples of each one):

- *Language* (a minimum set of chemical concepts and information)
- *The methodology of chemistry* (the fundamentals of analysis and synthesis, the basic chemical operations) (3) and
- *Quantitativeness* (the basis of chemical calculations to solve elementary problems and to acquire applied mathematical reasoning).

In accordance with these vertebral features we have developed a full and fresh pedagogical proposal for a high

Table 2. Examples of the Three Chemistry Literacy Elements

Language (chemical information)	Method (Analysis and synthesis)	Quantitativeness (Calculations and measurements)
Fever and antipyretics	Synthetic rubber	Effects of the concentration of alcohol in blood
Television: How it works?	NMR spectroscopy and body images	Antipollution stoichiometric calculations
Cancer and cis-platin	Aspirin synthesis	Human activities and its energetic intake
Greenhouse gases	Acid rain; causes, damages and prevention	Stomachal neutralization
Drugs and the brain	Corrosion and its costs	Energetic efficiency of photosynthesis

school chemistry curriculum that follows the five steps presented in Figure 3 and includes the nine units of chemical subjects shown in Table 3. The proposal insists on the relation of chemistry to the students' everyday lives, tends to remove the historical division between inorganic and organic chemistry, and deals with abstract concepts, such as atomic and molecular structure, once the presentation of the phenomenological aspects of chemistry has been settled.

Four written works have been developed to support teacher's training workshops, learning material and readings for the students:

(1) A Didactic Guide that contains key recommendations on the teaching of three subjects that have been recognized as "hard bones to pick" in chemistry courses, e.g. electronic structure of atoms, stoichiometry and chemical calculations, and states of matter.

(2) A set of 33 low-cost chemistry laboratory experiments (4), most of which have been taken from three UNESCO international meetings on experimental education in the Third World, and six Regional Labs in Latin America and the Caribbean, supervised by one of the authors (A. G.).

(3) An anthology of essays on chemistry and society (5) that is appropriate for use at the high school level.

(4) A textbook (6) that develops the chemistry subjects overlapped with short essays that emphasize chemical literacy, narratives on the history of chemistry in Mexico, data of Mexican chemical industries, domestic experiments, and interviews with some of the most prominent Mexican scientists.

Table 3. Chemistry Subjects in the Curriculum

Unit 1. Chemistry and our world
Unit 2. Diversity of nature
Unit 3. The aggregation of the states of matter
Unit 4. From molecules to atoms
Unit 5. Atomic structure
Unit 6 From atoms to molecules. the chemical bond.
Unit 7. Energy, equilibrium, and chemical kinetics
Unit 8. Acids and bases
Unit 9. Oxidation–reduction reactions

This new educational scheme represents an affordable change that can be managed by teachers, because it mixes old and new ideas: while keeping a sequence of chemistry subjects (in contrast, for example, to ChemComm), it considers the impact of the socially relevant chemistry on the students' everyday lives. Furthermore, it considers science as an integral entity in such a way that the specificity of chemistry does not avoid discussing its frontiers with other sciences. Astronomy (the origin of the elements), physics (the actual atomic structure), biology (genetic diseases) and environmental science (pollution in Mexico City) are only a few examples of an integral and relevant understanding of nature.

Within this scheme a series of teacher training efforts were undertaken mainly in two big high school Mexican systems with more than half a million students. One of them, called "Colegio de Bachilleres", has completely adopted this proposal since September 1992. Finally, there are plans to create a Chemical Education Center in the National University of Mexico to multiply the effect of these and other training activities.

It may be too soon to make a formal evaluation, but the enthusiastic answer of teachers in the workshops and some other preliminary results as the initial students' attitudes toward their chemistry course give us some confidence about the effectiveness of this project to improve and modernize high school chemical education in Mexico.

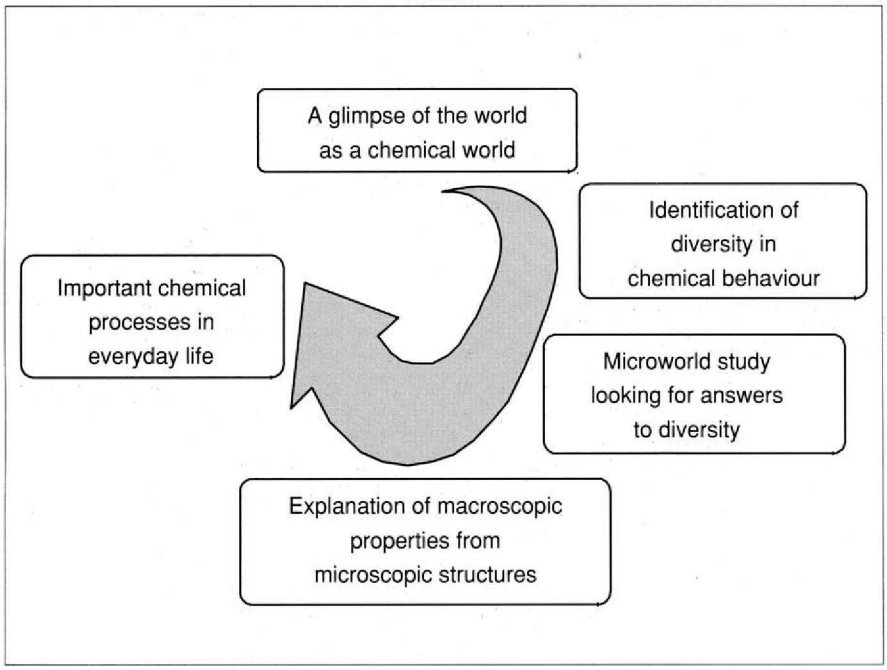

Figure 3. High school chemistry must start near to the student's everyday life. After the observation of chemical processes and phenomena in nature, the explanation of these natural facts requires the study of the atomic and molecular structure of matter, with which everyday chemical processes can be interpreted.

Acknowledgment

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