# Teaching Chemistry Through History: The Importance of The Periodic Table

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In early times chemistry was more an art than a science. The first applications of mineralogy and pharmacology were used empirically by ancient man to satisfying their needs. The alchemical period was focused on the search for the Philosopher's Stone and the Elixir of Life. In the sixteenth and seventeenth centuries, chemistry started developing more general and abstract theories, including the study of the key role gases play in chemistry. In the 18th century, Lavoisier and other French chemists revolutionised the view of chemistry in its experimental structure, theoretical principles and nomenclature. After this period chemistry became an autonomous science and, finally,[1] it was introduced in French secondary school level curriculum.

Chemistry is an important part of our daily lives. However, chemistry currently has a negative perception in public opinion. In general, people identify chemistry with the artificial, with environmental and ecological damage, and with disasters by industrial contamination. All of these factors, and others, have had a negative impact on public opinion.[2-3] Chemistry also has a bad image among students. Most students do not appreciate the impact of developments in chemistry on various parts of our lives: technology, health, agriculture, energy, etc. and that the results of progress in chemistry benefits all of society.

High school students learn a variety of topics that include: structure of the atom and characteristics of matter, radioactivity, Lavoisier's law, the periodic table of elements, organic compounds, etc. However, they usually don't know who made or discovered that law, when it happened or how it was found. In spite of chemical processes being in use from long ago, the history of chemistry is not usually taught in Spanish high secondary schools. The present authors consider that this absence is preventing a good social understanding of chemistry.[4]

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## Interest of Spanish/Catalan secondary school students towards chemistry

There are 17 Autonomous Communities in Spain; each develops its own independent education systems. The results herein derive from Catalonia.[5-6] Students from secondary schools (14-16 years-old) and high secondary schools (>17 years-old) were asked to complete a questionnaire about chemistry and their feelings about the subject. 321 questionnaires have been completed since 2003, of which 52% correspond to female students and 48% to male. Table 1 summarises the results from four courses.

Results showed us that over the past 5 years interest in chemistry, and also in general science, has been decreasing[7] in younger students. Only 30% of secondary school students will pursue high studies in science and only 5% will pursue chemistry. There have been similar findings throughout Europe.[8] In addition, chemistry has a negative perception among about 40% of secondary school students and high secondary school students who did not pursue science, with 4 out of 10 students believing that chemistry is bad and 7-9 out of 10 students believing that chemistry is difficult.

**Table 1**

**Interest of Spanish/Catalan secondary school students towards chemistry**

| Secondary school, 14-16 years old (n=162) | | |
|---|---|---|
| **Question** | **YES** | **NO** |
| Will you pursue high studies in science? | 30 % | 70 % |
| Will you pursue a career in chemistry? | 5 % | 95 % |
| Do you find learning chemistry is difficult? | 75 % | 25 % |
| Do you believe chemistry is dangerous and bad? | 44 % | 56 % |

| High Secondary school, >17 years old, no science courses (n=84) | | |
|---|---|---|
| **Question** | **YES** | **NO** |
| Will you pursue a career in chemistry? | 0 % | 100 % |
| Do you find learning chemistry is difficult? | 95 % | 5 % |
| Do you believe chemistry is dangerous and bad? | 42 % | 58 % |

| High Secondary school, >17 years old, science courses (n=75) | | |
|---|---|---|
| **Question** | **YES** | **NO** |
| Will you pursue a career in chemistry? | 8 % | 92 % |
| Do you find learning chemistry is difficult? | 39 % | 61 % |
| Do you believe chemistry is dangerous and bad? | 12 % | 88 % |

The answers from high secondary school students who are following science courses is worrying because, though they want to become scientists, 4 out of 10 students believe that chemistry is difficult. Why do so many of our future scientists believe that chemistry is difficult? One of the explanations could be that there is currently no relationship built between spectacular science, used to attract young students, and theoretical chemistry in secondary school's curricula. Additionally, chemistry instruction in high secondary school courses occurs only at the symbolic level (technical and unfamiliar language).[9] Furthermore, Nurrenbern and Pickering and Sanger *et al.*[10-11] have shown that students who can resolve mathematical chemistry problems will often still have trouble in answering conceptual problems about the same subject matter.

When most students think of chemistry, they think of mathematical problems, coloured water, symbols, and the cryptic periodic table. They don't usually think of the history of chemistry, a very rich history which teachers could possibly use to help motivate the students and encourage interest in all aspects of chemistry.

In addition, we correlated these results with the amount of history of chemistry in Spanish and Catalan chemistry textbooks. Most of them neglected this subject, though some books did contain a few illustrations (from Lavoisier, Arrhenius, Mendeleev, Gay-Lussac, etc.) or a few words about a small number of scientists (e. g.: "*Who was Dimitri Mendeleev and what did he do in chemistry?*"). However, there are a small number of chemistry textbooks with short general biographies (usually of about around 150 words) for several prominent chemists, such as Dimitri Mendeleev, Linus Carl Pauling and Niels Bohr.

The publishers of Spanish and Catalan chemistry textbooks can choose to include or omit, at will, part of "The History of Chemistry" because it is not present in current secondary school chemistry curricula.[12] Since Lavoisier´s time, and even before, the inclusion of history to chemistry textbooks[13-14] has been examined. Discussions between Lavoisier and Fourcroy in the XVIII$^{th}$ century[15-16] are known. Fourcroy supported the addition of references to history in textbooks, while in contrast Lavoisier did not agree with these additions. The leaving out "The History of Chemistry" into chemistry textbooks could well be a reason why our students have lost interest in chemistry.

In Figure 1 are shown illustrations from chemistry books currently used in Spanish/Catalan secondary education. They depict, Lavoisier (without any explanation), Marie Curie and Dimitri Mendeleev with short captions, which are given translated, below.


* *Marie Curie made some important discoveries related to radioactivity and several isotopes.*
** *Who was Dimitri Mendeleiev and what did he do in chemistry?*

Generally, our secondary school students have lower interest in topics in chemistry than in other areas of science, such as biology or physics. This lack of interest is difficult to tackle. These are the problems to be confronted in our attempt to change education in chemical topics. In the following ways it is hoped to open up history and the nature of chemistry and increase interest in all aspects of chemistry.

## "The History of Chemistry" in the classroom: an educational experience

In order to bridge the gap between chemistry and its history, some changes are proposed in the chemistry curricula for students in their last year of secondary school, as well as for students in their first year of high secondary school. The aim of the project has been to find historical topics in chemistry which will help students understand some concepts more easily.

A few years ago, beginning in 2003, a number of secondary school pupils were made to study some chemists' biographies[17-20] such the alchemists (Paracelsus), Lavoisier, Döbereiner, Meyer, Mendeleev, Rutherford, Marja Sklodowska, Seaborg, etc. Each student or group that had researched a given scientist then made a 15-minute presentation on his/her designated chemist and answered questions posed by their fellow students. By this means, each had the opportuni-

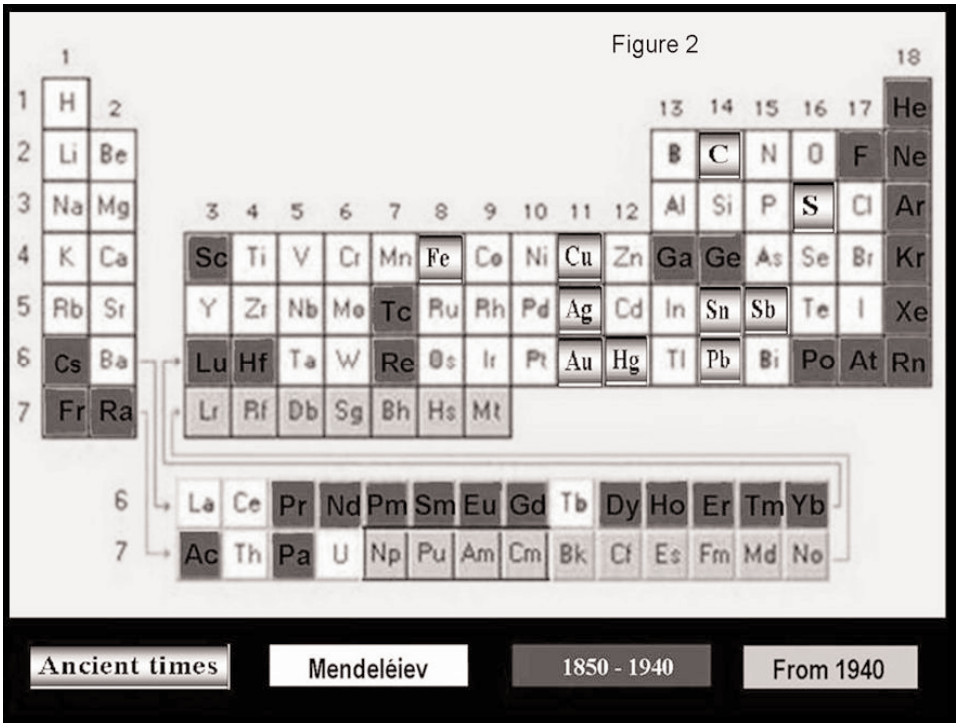
ty to learn about the lives of every chemist who had been researched by the class, either through direct research or through the presentations put on by their fellow students. In this way they became better equipped to compare and understand chemistry research and methods from different time periods in history.

Some of the students who participated in the previous class went on to enrol in high secondary school where they were more involved with chemistry than those who did not make this special study. All of these students, during their last year of secondary school, studied the biographies of Dimitri Mendeléiev and Lothar Meyer gained an understanding of the significant contribution both scientists made to the design and development of the periodic table of elements. Furthermore, by having the students also read the Seaborg biography[21] it helped them understand that new elements can be discovered at any time.

The periodic table of the chemical elements was created in 1869 by Dimitri Mendeleev.[22] The periodic table is a way of presenting the chemical elements. Mendeleev detected a clear relationship between putting chemical elements in atomic mass order and a regular variation of chemical elements properties which take place periodically. He also predicted new elements and placed all of the discovered elements into this new classification. The periodic table has been extended over time as new elements have been discovered. At the moment, it contains 111 confirmed elements.[23]

Our high secondary school students were divided into groups[24] to summarize the historical development of chemical elements and organized them into the periodic table of chemical elements. The elements were divided into four groups, related to the period in which they were discovered; Ancient Times, Mendeleev, 1850-1940, and from 1940 as illustrated in Figure 2. It was created for chemistry high secondary school students during the 2006 to 2007 course.

Figure 2 can be used as a tool to help increase the knowledge and understanding of chemistry among students. First, and most important for our students, was Mendeleev's ability to predict in 1870 the existence and the properties of eka-silicon, eka-aluminium, and eka-boron (names given by Mendeleev) which corresponded to germanium (Ge), gallium (Ga), and scandium (Sc) respectively. Gallium was discovered in 1875, scandium in 1879 and germanium in 1886, these three chemical elements were found to have approximately the same properties that Mendeleev had predicted for his three elements. Unfortunately this information is often missing from chemistry classes despite the fact that this part of history is very motivating to students and builds additional interest in general chemistry.




Secondly, students can clearly see that there were many jumps in the discovery of chemical elements, and our knowledge of chemistry has not been steadily increasing with time. Most of the important jumps in "The History of Chemistry" can be correlated with new laboratory tools and approaches to research, as illustrated in Figure 3.

The concepts and tools listed in Figure 3 have been utilised as an introduction to "The History of Chemistry" classes. The goal of this approach was to identify and create the best possible learning environment in the chemistry classroom. In this way, some chemistry subjects have been taught in parallel with changes in laboratory equipment/apparatus; *Nature of matter* with the clay furnace; *States of matter and gas laws* with glassblowing; *Ions and dissociation of water* with electrolysis; *Atomic structure and bonds* with spectroscopy; *Inert gasses* with distillation of liquid air; and *Radioactivity* with Nuclear reactions.

At the end of the course, feedback was collected from our students via a new questionnaire. The results are summarised in Table 2.

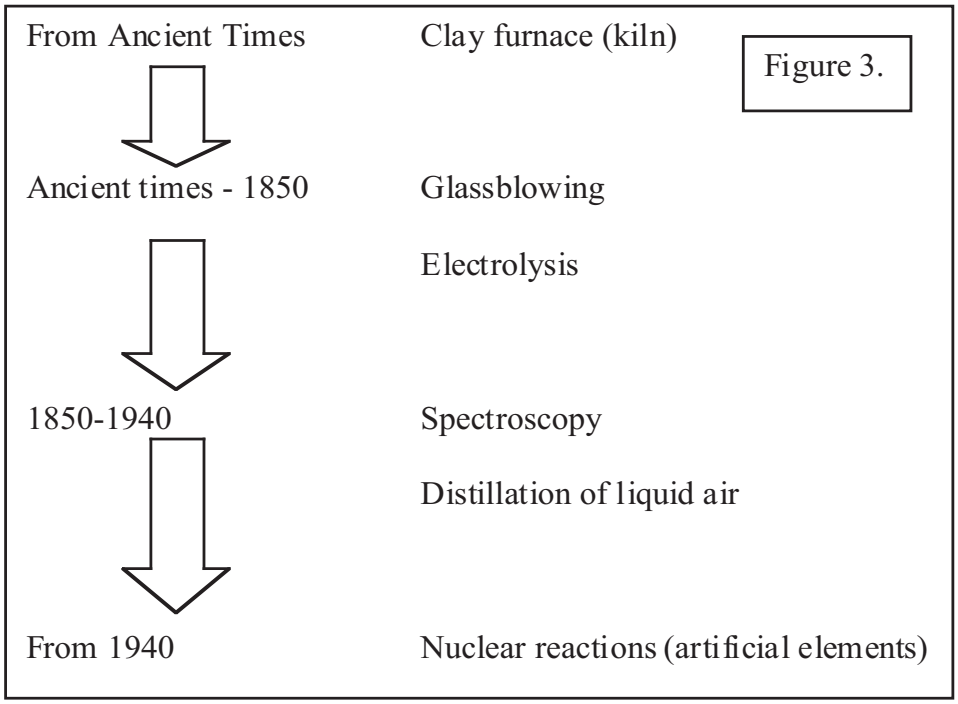



**Table 2**

**Feedback from Chemistry Students in High Secondary School Regarding "The History of Chemistry" Classes**

| Question | YES | NO |
|---|---|---|
| Do you believe that learning the history of chemistry would improve overall understanding of chemistry? | 72% | 28% |
| Do you believe that the history approach required greater attention compared to a regular chemistry class? | 20% | 80% |
| Do you believe that you gained in-depth understanding of chemical concepts from "The History of Chemistry" classes? | 80% | 20% |
| Was learning chemistry difficult in "The History of Chemistry" classes? | 16% | 84% |
| Was learning chemistry exciting in "The History of Chemistry" classes? | 88% | 12% |

As you can see from the data in Table 2, most students considered these classes valuable for increasing their chemistry knowledge (7-8 out of 10) and also stated that this approach increased their interest in chemistry and changed their previous perception of chemistry (2 out of 10 believe that chemistry is difficult, which is the same answer received for question 2 in Table 1). Finally, students indicated that The History of Chemistry classes caused greater interest in continuing to study chemistry.

## Conclusions

High secondary school students involved with chemistry will often intend to become scientists and/or chemists. However, they need a more in depth education of chemistry than is presently provided in secondary school in Spain. The History of Chemistry class aims to provide students with a new approach to learning chemistry and we believe chemistry teachers in general and Spanish/Catalan in particular could employ this new tool to great effect. These chemistry lessons teach secondary school students to appreciate the relationship between chemistry, the lives of chemists' and "The History of Chemistry" as well as providing them with an increased knowledge of general science. In addition, through this method they had an increased understanding of the concept of periodicity related to properties and reactivity of some chemical elements.

Teaching chemistry, by way of its history can again make it attractive to young students. We propose that this aspect of chemistry be present in the Spanish science secondary school curricula.

## Acknowledgements

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