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Students' Motivation for Chemistry

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1. European observations

The youths' disaffection for science in general and for chemistry in particular is widespread in Europe.
The situation is sometimes catastrophic: in Belgium at the UCL, 120 students graduated in chemistry in 1972 (called "licences" at the time); nowadays, there are only a dozen of them a year.
Everywhere, from Bulgaria to Spain, the same arguments come up; they can be divided in two categories:

- **Society-related arguments.**
Up to the years 70, science and chemistry were considered as factors of progress (remember for instance the space missions, it was relatively easy to convince the public opinion of the positive technologic consequences). A 180 turn was made at the time after a period of disillusion, the opinion no longer considered science as a source of progress. Environmental concerns (which are legitimate) have taken precedence and the image of chemistry was tarnished (pollution, accidents, secrets and mysteries of chemical industries). It must be pointed out that sustainable development and chemistry are not mutually exclusive, (cf. essenscia report http://www.essenscia.be/01/MyDocuments/SD_REPORT_ESSENSCIA_2011.pdf) but this idea is not easily accepted by the public. Just mentioning it is suspicious. There has been much disinformation (such as the opposition between "chemical" and "natural" product) which is still spreading.
Career prospects are weak (particularly in Bulgaria and in Greece). It is true that society shows more consideration for a doctor, an economist or a manager, than for a researcher in chemistry. Career as a science teacher, like other teachers from primary school to university, has also lost much of its aura.

- Subject-related arguments.
Studying chemistry is considered as difficult or very difficult.
In secondary schools, chemistry is taught in a too theoretical manner, little space and time is dedicated to experiments. Yet chemistry is before anything an experimental science. This situation is partly related to the withdrawal of laboratory sessions and equipment in several schools but also to some teachers' "fear" of chemical products. The methods used are little appealing: the nomenclature is often learned "by heart", teaching is not often contextualised… As they are currently designed, the programmes leave chemistry too little time (especially to make experiments). Unlike physics or biology, chemistry does not seem to involve a great challenge.

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2. Personal observations

There is nothing new here and all the initiatives taken do not seem to really change anything:

- the creation of promotion units for university science (such as Scienceinfuse at UCL http://www.uclouvain.be/scienceinfuse.html),
- science promotion activities organised by French-speaking universities for schools and the general public such as "le Printemps des sciences" (http://www.sciences.be/),
- the publication of a second edition of the book "ChemCom, Chemistry in the Community" USA, although it is from 1995,
- the commendable efforts to restore the image of chemistry and encourage the youths to study it made by industries (such as Essenscia and many others, Agfa Gevaert DIDAC….) …

So, what should be done?

Chemistry is a science the teaching of which poses problems, but one has to be **"imbued with chemistry"** to understand those errors and thus, only those who have really assimilated the sense of chemistry will be able to validly learn chemistry! On the contrary, all those who have renounced, thinking that they would not understand anything about chemistry cannot, will not be interested. The above-mentioned ideas will make sense only to those who belong, at least a little, to the "world of chemists".
According to Bernard Tinant, professor in the first year at UCL, chemistry, the science of matter transformations, raises two great questions:

With what (which reagents) and in which conditions can I make the product X?

If teachers do not pay attention to the problems of jargon, of symbolism and in general of chemists' language, they will answer this question by writing an equation with formulas without explaining why this symbolism is used. The student will very soon be led to **chemistry "on paper".** Chemistry will seem harder than Chinese with a complete loss of meaning. It must be noted that many students who start the first year at university **mix up reality and formulas**… The remedy is clear, we must go back to **experimentations!**

Being aware of the recipe, how much A and B should I use to make 10 Kg of X?

The problem here is human, we have always liked seeing what we play with, we make things our own more easily when we can handle them, yet atoms and molecules are too tiny to do so. We have to imagine the microscopic world, we cannot comprehend it, "grab it", which is a problem for many people, or even most students. The change of scale that appears when introducing the concept of mole as a unit of quantity of matter is not clearly explained, and the comings and goings between **the microscopic and macroscopic worlds** are not numerous enough.

Beside the complexity of the language, teachers are confronted with those two difficulties when the fundamental bases of chemistry are addressed (in second grade in Belgium). It is probably too early, at least the modelling aspect, when one consider the cognitive and psychological development of 16 year old students. This results in a reaction of reject. Considering that chemistry is taught by piling up concept on top of each other, we understand why people who are disgusted with chemistry are more and more numerous.

3. New ideas for remediation

More experiments in the class, specific preparation for studies, ICT associated with systemic approaches…

-To reintegrate **more experiments in the class**, greater means are necessary, in terms of equipment, and infrastructure and in terms of training of the teachers. Initiatives are taken (continuing training, new frame of reference for skills…)
-**Specific preparations for higher studies in chemistry should be created** but … it is not in the news in the French Community of Belgium where the education system is completely "open". Should we, like when beginning studies in medicine, have assimilated a set of prerequisites to be allowed to take this field of study?

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-A promising idea would be **to associate the use of ICT, experiments and a systemic approach**… It is not an easy job, because the same mistakes can be made but these are surely realistic ways to "see" and "make" or, even better, to "build" experiments.
-In order to propose a new conception of chemistry learning which associates ICT, experiments and systemic approach, we first address what needed to be taken into consideration **to "motivate" the students to learn chemistry. To do so, we have used Viau's criteria and indicators adapted to the teaching of chemistry.**

- **Analysis of the sources of (de)motivation in the school context**

Rolland Viau proposes a list of practical advice to motivate students. If we try to put those recommendations in the context of a chemistry course, specificities appear. They are enumerated below in italic.

1. <u>The teacher must take care not to harm students' motivation.</u>
It is in the teacher's best interest to be aware of personal features that might harm students' motivation and to try to counteract the negative effects.
The teacher's ability and motivation
-Master one's subject
Teachers are not all trained as chemists.
For a chemical phenomenon to take place, several specificities need to be taken into account (the temperature, catalyst…)
-Adapt it to the students
The gap between the academic knowledge taught in universities and school subjects can be huge.
-Define the contents
In the laboratory, the substances used (hydrogen chloride, sodium hydroxide…) are foreign to the student. Chemical phenomena known to the students (meat cooking) are often too complex to be accessible.
-Provide examples and analogies
Chemistry describes the behaviour of matter with the help of atoms, molecules and ions, real objects that cannot be perceived by senses, by particular functioning. Moreover, those objects are more numerous than anything the student could comprehend.
-Be willing to teach chemistry
The student who starts studying "hard sciences" is interested in inert matter. The work of teacher nowadays is particularly focused on learning and requires a people-oriented profile.

2. <u>The teacher has to improve one or several aspects of their teaching</u> to increase students' motivation. The teacher should bring their students to:
-Make connections between what they know and the new subject.
Chemistry is the most cumulative scientific discipline. Each knowledge item is based on the previous one. If a notion is not taken in, the whole knowledge chain is disrupted.
-Solve problems that will help them better understand the reality around them.
We can apply to chemistry the metaphor of the fish that asks: "where is the ocean everybody talks about?" It is difficult to show students a place where molecules are not active. These multiple particular situations assume that chemical phenomena that are accessible to students and present in their immediate surroundings are necessarily anecdotic.
-Play an active and dynamic role.
Reagents' aggressiveness, resulting thermal exchanges, particular restraints linked to the handling of the reaction… are many curbs on students' initiative.
-Propose activities for assimilation:
1. Begin with an anecdote or a challenge
   Challenges are often avoided for security reasons. Historical anecdotes are numerous but little known. Literature on the history of sciences contains many mistakes.
2. Question the students on their preconceptions
   Students' preconceptions regarding chemistry are terrible: chemistry is dangerous and polluting, the cause of much harm in industrial societies. Benefits are undervalued.
3. Present a planning of the course in the form of questions
   Predicting the behaviour of matter requires an expertise of molecular field that few students achieve.

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4. Present the concept in the form of diagram
5. Give examples that interest students
6. Use analogies
7. Multiply exercises to set up automatic reflexes

Unlike in other subjects, knowledge that is useful to man increases exponentially. The quantity of knowledge to install creates a continual race to cover the whole programme.

-Propose activities for integration. An integration activity requires from the students to use on their own initiative the knowledge and skills acquired in the learning.

Chemistry is a particularly complex science, in which beginners need support from an expert.

-Assessments influence motivation

- **ICT and systemic approach to chemistry**

In the light of this analysis, it emerges that chemistry is an unusual subject. Learning it is delicate.
Given that knowledge societies change the social order they address to the school and that the school public and its motivation sources are evolving, the teacher finds themselves with new constraints that require a change of professional attitude.

This European project aims at optimising the learning of chemistry. Within this framework, Pierre Hautier and Jean-Luc Pieczynski postulate that this change of paradigm can be modelled: the analytical process needs to be completed with a systemic approach to learning ICT, by enabling to dynamically model the microscopic universe, participate in this transformation.
Therefore, in collaboration with Myriam De Kesel and Bernard Tinant, who train biology and chemistry teachers at UCL, teaching sequences on chemical concepts that are particularly difficult to teach and learn, associating ICT and systemic approach, will be proposed and tested in secondary school classes (Belgian schools that are partner to the European project). Their impact on motivation, and thence on students' learning, will be assessed.

Conclusion:

Chemistry is a particularly complex science, in which beginners need support from an expert in order to:

1. master the scientific jargon
2. master it through experiments
3. master it through the use of ICT

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