Chemistry As an Exemplary Case Study in Italy: Few Hints of Reflection from the CIAAU Project

Carnasciali Maria Maddalena[1], Ricco Laura[1], Parrachino Irene[2], Borsese Aldo[1]

[1]*Department of Chemistry and Industrial Chemistry – University of Genoa, Via Dodecaneso 31, 16146 Genoa – Italy*
marilena@chimica.unige.it

[2]*Comprehensive Institute Ronco Scrivia, Via Vittorio Veneto 1, 16019 Ronco Scrivia (Genoa) - Italy*

Abstract

The life-long learning of scientific subjects, chemistry in particular, is deeply in crisis, not only in Italy, but also all over Europe. In the light of this evidence, the scientific community feels the need of finding out the motivations that caused the rejection and the demonization of chemistry not only by adult but also by young people, which is more alarming. The 'Chemistry Is All Around Us' project was funded by the European Commission with the aim of finding a concrete solution to crisis of scientific disciplines. This paper is focused on a special issue of the project: a case study, carried out in Italy through interviewing twenty people between science teachers and adult learners; the analysis of the national situation, as well as the results of the interviews, led to the proposal of a strategy aiming at reducing the citizens' distrust toward Science, chemistry in particular.

Keywords: *lifelong learning, chemistry education, image of chemistry, case study, crisis of science*

Introduction

The 'Chemistry Is All Around Us' (CIAAU) project has been funded with the support of the European Commission in the framework of the Lifelong Learning Programme, Key Activity 1, with the aim of promoting lifelong learning of scientific subjects, chemistry in particular.
The identified background of the project idea relies on the evidence of common needs within the countries involved and in Europe in general, related to the lack and insufficient diffusion of scientific culture and awareness, which, starting from the school level (primary and secondary education), affects all grades of educational and training systems and therefore

citizens in general (Convert 2005; EACEA 2011; European Commission 2004; European Commission 2007; OECD 2007; Osborne and Dillon 2008; Osborne et al. 2003).

Promoting lifelong learning strategies for scientific issues is much more difficult, compared to other subject areas (e.g. humanistic subjects, business management, language learning) as, when the compulsory education ends, those who are not interested in science are much more likely to completely abandon the subject. Among the scientific fields, chemistry is identified as an exemplary case study, as it is recognised as one of the most problematic subjects. That is because chemistry suffers from a growing unpopularity also due to the fact that the media often make improper connections between chemistry and the ideas of pollution, health threats, manipulation of natural structures etc.

Task of the school should be to provide students and citizens with conceptual and knowledge tools so that they can understand how chemistry may really improve the quality of their lives and how, for the damages attached to this science, men should be blamed as they have made an improper use of it for economical purposes.

In this context the CIAAU project intended to:

- identify barriers that affect the lifelong learning of scientific subjects;
- carry out a comparison among the strategies implemented for the promotion and diffusion of chemistry in the six European countries involved (Bulgaria, Czech Republic, Germany, Greece , Italy and Turkey);
- develop strategies and tools for the promotion of lifelong learning in scientific subjects and in chemistry in particular.

All materials produced and collected have been uploaded on the project portal (http://www.chemistry-is.eu/) and can be looked up by anyone interested.

Case Study

In order to identify the main obstacles to lifelong learning in scientific subjects, twenty interviews have been carried out: ten to teachers (of lower and upper secondary schools) and ten to adults who haven't engaged a scientific carrier. The aim was not to obtain valuable statistic data, but rather to gather hints for reflection, useful to propose a suitable strategy for implementing lifelong learning of chemistry though analysed within the national scenario.

Interviews to adult learners

Eleven questions have been elaborated to be asked to ten adult learners:

1. Why have you decided not to continue your studies in the scientific field after upper secondary school? (Please justify your answer)
2. What are the major difficulties you have found in studying chemistry at school? (lack of basic requisites, cognitive problems linked to some contents, other). (Please justify your answer)
3. How would you assess your knowledge of chemistry? (poor, fair, good, very good).
4. Should you have any scientific curiosity, would you try to satisfy it? If so, how would you do it?
5. Do you think mass media provide access to suitable scientific information (particularly on chemistry) that you can understand? (Please justify your answer)
6. What do you associate with the adjective "chemical"?
7. If you melt 5 grams of salt in 100 grams of water, the solution obtained will weigh:
   ▲ 105 grams;
   ▲ between 100 and 105 grams;
   ▲ 100 grams
   (Please justify your answer)
8. We sometimes perceive the presence of some substances through the sense of smell, as they give off a characteristic scent. Do you think it is made of material or immaterial particles? (Please justify your answer)
9. Can you think of an example of a pure substance in the solid state?
10. Can you think of an example of a pure substance in the liquid state?
11. Can you think of an example of a pure substance in the gaseous state?

The interviews to the "adult learners" have been purposely thought to be addressed to people who haven't graduated or who have attended school in a non-scientific field.

Hence, the first two questions aim at investigating personal motivations of choices as far as the school track is concerned; particularly the second question aims at clarifying if the choice of a non-scientific faculty was due to the difficulties met while studying sciences up to secondary school.

Questions from 3 to 5 check the interviewee's attitude towards sciences in everyday life; due to the object of the project, questions 4 and 5 ask if, according to the interviewee's opinion, the media and the internet can be somehow considered useful formative and informative channels in the scientific field.

Question number 6 highlights the fact that the word “chemical” is mostly associated with something negative, as opposed to the word “natural”.
The last 5 questions test some basic scientific competences: the concept of mass preservation, the awareness of smell and gas substances materiality, the concept of pure substance in the different states of matter.
The integral interviews are not available in this paper but a summary of the answers for each adult is given below, as well as the area they have chosen to specialize in.

- Adult 1 (female, subject studied: modern literature)
This person hasn’t continued scientific studies because she was more interested in the literary area (languages) and she didn't feel gifted for scientific subjects. On the other hand she had no difficulties in studying chemistry at school, thanks to good supports at home, overcoming any possible teachers' lack of knowledge.
Self-evaluation about her knowledge of chemistry is: “poor”.
About the scientific information provided by the media she thinks that the information given is not reliable, because the media are manipulated and their main aim is conditioning people more than informing them.
The word “chemical” is associated with non-natural products or substances.
She answered correctly to the basic chemistry test, except for the item about the materiality of scent.

- Adult 2 (female, subject studied: languages)
She hasn’t continued scientific studies because she wasn't particularly interested or gifted for Maths. Her main difficulties in studying chemistry at school were due to the teacher's methodology. Self-evaluation about her knowledge of chemistry is: “poor”.
As for the scientific information provided by the media, she thinks that the information given is not deepened enough: it can be understood only if simplified and made banal.
The word “chemical” is associated (as an association of ideas) with test tubes, machinery, overall, labs, factories, drugs: she believes that in many people’s minds “chemical” corresponds to “artificial”, but it’s not correct because there are chemical bounds also in nature.
She answered correctly to the basic chemistry test.

- Adult 3 (male, subject studied: art and professional formation)

He hasn’t continued scientific studies because he preferred to follow his artistic attitude and he wasn’t particularly interested in the scientific area. He doesn’t remember much of his chemical studies, but chemistry was not so difficult, just a matter of memorizing.
Self-evaluation of his knowledge of chemistry is: “poor and lacking”.
He thinks that the information provided by the media is superficial.
The word “chemical” is associated with non-natural drugs.
His answers to the basic chemistry test about the concept of pure substance were wrong.

- Adult 4 (female, subject studied: Italian literature)
This person hasn’t continued scientific studies because she wasn’t particularly interested and she had difficulties in the scientific area, especially in Maths, too abstract for her. She doesn’t remember having difficulties with chemistry (she studied microbiology and hygiene at University).
Self-evaluation of her knowledge of chemistry is: “poor”.
She thinks that the information provided by the media is far from common people’s real needs.
The word “chemical” is associated with pollution of rivers and toxic things in general.
She answered correctly to the basic chemistry test.

- Adult 5 (female, subject studied: art and professional formation)
She hasn’t continued scientific studies because she was more interested in the socio-humanistic area. Her major difficulties were connected to the specific language: some names were difficult to learn and to link to their meaning and they could only be memorized.
Self-evaluation of her knowledge of chemistry is: “poor”.
She thinks that the information provided by the media is quite good: documentaries are accessible if a simple language is used.
The word “chemical” is associated with tests, scientists and cloning.
Her answers to the basic chemistry test about dissolution and materiality of scent were wrong.

- Adult 6 (male, subject studied: professional formation)
He hasn’t continued scientific studies because he wasn't interested. He doesn't remember studying chemistry at school so he thinks that he obviously didn’t do much and he understood little of it.
Self-evaluation of his knowledge of chemistry is: “very poor”.

He doesn’t know if the mass media help people to get “suitable” information, but he thinks they are positive all the same.
The word “chemical” is associated with pharmacy, medicines and drugs.
His answers to the basic chemistry test were wrong

- Adult 7 (female, subject studied: languages)
This person hasn’t continued scientific studies because she attended a school that was dealing with a linguistic project, so she went on that area. She found no difficulties in studying chemistry at school, she loved it.
Self-evaluation of her knowledge of chemistry is “poor”.
She thinks that the mass media don’t deal much with scientific questions because, in her opinion, it’s too complicated.
The word “chemical” is associated with formulas, analysis and the table of elements.
She didn’t answer correctly to the basic chemistry test.

- Adult 8 (male, subject studied: professional formation)
He hasn’t continued scientific studies because he was going to continue his father’s job (carpenter) and he consequently chose a specific school. He found difficulties in studying chemistry at school, because he didn't understand it.
Self-evaluation of his knowledge of chemistry is “poor”.
He thinks that maybe the mass media do not provide adequate information, but sometimes there are programs that try to explain scientific matters using a simple and easy-to-understand language.
The word “chemical” is associated with the verb “to distrust”.
He answered correctly to the basic chemistry test.

- Adult 9 (male, subject studied: professional formation)
He hasn’t continued scientific studies because he wanted a school that could prepare him for a working career. He didn't find particular difficulties in studying chemistry at school.
Self-evaluation of his knowledge of chemistry is: “poor”.
He thinks that the mass media do not provide adequate information, because there are few programs.
The word “chemical” is associated with the verb “to mix”.
The answers to the basic chemistry test were not completely correct.

- Adult 10 (male, subject studied: music and philosophy)

This person hasn't continued scientific studies because he was more attracted by philosophy. He didn't find particular difficulties in studying chemistry at school: he used to "study it diligently", but he "didn't understand it deeply".

Self-evaluation of his knowledge of chemistry is: "poor".

He hasn't got an opinion about the quality of information provided by mass media.

The word "chemical" is associated with labs.

His answers to the basic chemistry test were wrong.

Summarizing the most noteworthy points of the interviews, when people were requested to tell their personal experiences with chemistry and science, their answers were 'I was interested in other areas' and/or 'I was not gifted for...'. But at lower secondary school level, it's necessary to work harder to build and consolidate some basic abilities apart from personal tendencies, in order to educate aware citizens. Many referred to the role that memory plays in learning chemistry, even a person who 'loved' the subject considering it a 'game': nobody seemed to remember their struggle to understand a concept. The result is that everybody consider their knowledge in chemistry poor.

People interviewed tend to use the Internet to satisfy any scientific curiosities, but without using a critical discernment (they merely rely on search engines, they don't surf specific sites, at most they compare the information from different sites in order to check their reliability). On the other hand, as someone said, it is necessary to already have a good level of knowledge to be able to realize a possible low quality of the information found.

Even if they underlined some perplexities for the kind of scientific contents offered by the media (they are exploited, they simplify concepts making them banal), the general attitude towards scientific spread and popularization was positive.

The answers to question 6 confirmed the fact that chemistry is still associated with negative ideas, pollution in particular, as opposed to nature.

The answers to the last questions (7-11), aiming at checking whether some basic chemical concepts were or were not acquired and the general attitude towards the subject, showed some lacks and misunderstandings. Fig.1 evidences the low number of correct answers at these questions.

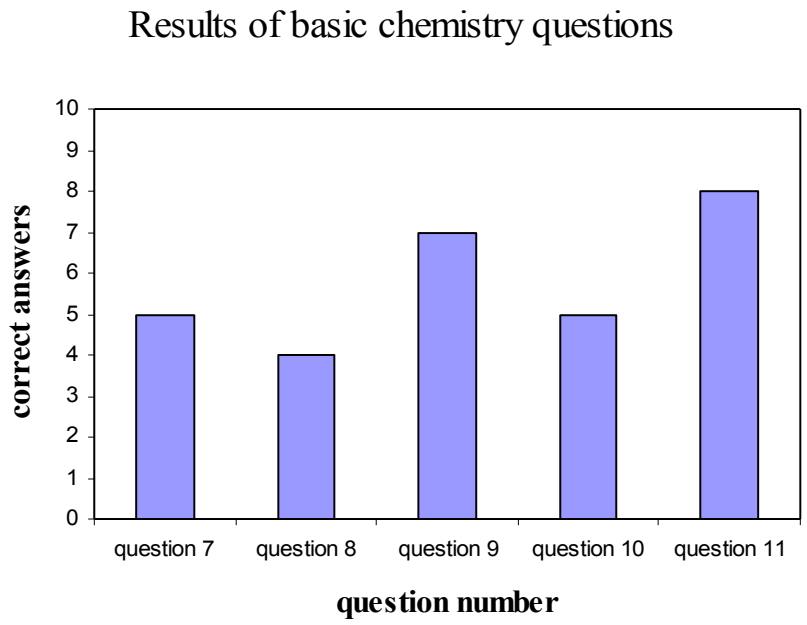

Fig.1. Assessment of basic chemistry skills of the ten adults interviewed

It is interesting to note that only five of the ten adults answered correctly to question 7, despite the help from the three answers provided. Concerning this question, the wrong answers are reported below, in order to underline that people usually have confused ideas even about very basic concepts, as the weight or the states of the matter:

- "Between 100 and 105 because it disperses"
- "I don't know, I should try. I think between 100 and 105 because if salt dissolves and becomes liquid, it will probably weigh less than the granules"
- "I should think ...100 because it dissolves. And if water boils, it always happen at 100"
- "100, because, when salt dissolves, we only have a liquid. However, water has to be measured in litres!"

Interviews to teachers

The following questions have been asked to ten teachers:

1. What do you think the reasons for major difficulties in learning chemistry at school are? (lack of basic requisites, cognitive problems linked to some contents, other). (Please justify your answer)
2. What major difficulties do you have in teaching chemistry? (lack of labs, lack of time, other) (Please justify your answer)

3. What kind of courses - if any - on didactics of chemistry have you attended? (Please specify whether the courses were mainly based on theory or on practice)
4. Why do many young people quit learning chemistry and, in general, scientific studies after upper secondary school? (belief that chemistry is difficult, or that a particular attitude is needed, other.) (Please justify your answer)
5. How could young people be helped take up scientific studies after upper secondary school? (Please justify your answer)
6. Which initiatives has your country undertaken in this direction?
7. Have you ever taken part into a research project concerning scientific learning?
8. Could you mention any recent research you have heard of, that might be useful to our project?
9. Could you suggest any other areas of research that might be useful to our project?

The teachers interviewed work in lower and upper secondary schools.
The first two questions aim at testing difficulties of the teaching/learning process in the scientific field, both from the pupil (question 1) and the teacher's point of view (question 2).
Assuming that many young people leave scientific studies after upper secondary school, questions 3 and 4 ask the interviewed teachers what, in their opinions, the motivation is and what could be done to steer young people towards attending scientific studies after upper secondary school.
The last 4 questions refer to projects for training, researching and spreading of scientific education in Italy: the teachers are asked if they know any project to steer learners towards scientific studies, if they have ever taken part to any research project, if they know any initiative or research linked to the "CIAAU" European project (briefly described by the interviewer before performing the questioning).
The summaries of the interviews are listed below and the disciplines taught are reported in brackets.

- Teacher 1 (Maths and Sciences at lower secondary school)
The teacher doesn't deal much with chemistry with her students. She says that, generally speaking, they remember it. She believes that teachers don't often have adequate knowledge in the field and there are problems connected with safety and security (lack of lab technicians).

The teacher thinks that many young people quit learning chemistry and, in general, scientific studies after upper secondary school because of a bad teaching methodology in upper secondary schools, where it's often considered a "second class" subject. Giving more importance to chemistry in technical and scientific secondary schools might help students to take up scientific studies.
She cannot describe any initiative in the field of promoting lifelong learning and she has no suggestion.

- Teacher 2 (Maths and Sciences at lower secondary school)
The teacher thinks that the main difficulties for students in learning chemistry at school are due to cognitive obstacles in some contents, for example microscopic structure of matter. She says that her major difficulties in teaching chemistry are lack of labs, which forces the teachers to work mainly on theory, and the complexity of planning significant and possibly cross-curricular lessons.
The teacher thinks that many young people quit learning chemistry and, in general, scientific studies after upper secondary school because in secondary school chemistry is studied mainly from a theoretical point of view.
Moreover new branches of engineering take matriculations away from "pure" scientific branches, because they provide a better access to employment. Stimulating students' curiosity towards basic scientific researches might help students to take up scientific studies.
She knows some initiatives in the field of promoting lifelong learning: PLS (project for scientific degrees) by the University of Genoa, a Master in Scientific Communication by University of Trieste, which helps to become ~~a~~ scientific communicators, and summer schools for teachers organized by universities. She has no suggestion.

- Teacher 3 (Maths and Sciences at lower secondary school)
This teacher thinks that the main difficulties for students in learning chemistry at school are "linked to the fact that chemistry is difficult to focus and to control". As a teacher, the difficulty is that she is worried to give wrong and rough models to her students, because she thinks she doesn't know much about chemistry and also books have many mistakes.
The teacher thinks that many young people quit learning chemistry and, in general, scientific studies after upper secondary school because universities provide low level professional opportunities: she can't imagine how to motivate the students to take up scientific studies

because there should be actions also on the job market and on the University-employment link.
She doesn't know any initiative in the field of promoting lifelong learning and she has no suggestion.

- Teacher 4 (Maths and Sciences at lower secondary school)
The teacher thinks that main difficulties for students in learning chemistry at school are due to the fact that they don't have proper tools to face it: some essential cross-curricular abilities are also lacking. Teachers are sometimes not enough prepared to correctly approach the subject and labs are not enough.
Many young people quit learning chemistry and, in general, scientific studies after upper secondary school because teachers are scarcely motivating and supply students with an inadequate preparation. Involving students in activities connecting secondary school and University might help them take up scientific studies.
Among the initiatives in the field of promoting lifelong learning, she only knows PLS (project for scientific degrees) by the University of Genoa. She has no other suggestion.

- Teacher 5 (Maths and Sciences at lower secondary school)
The teacher thinks that the main difficulties for students in learning chemistry at school are due to the microscopic aspects of the subject, because many students still lack of the ability of abstracting and books don't help much as they keep mixing microscopic and macroscopic aspects. Teachers are submitted to pressure from school and parents as far as the school curriculum is concerned: when a teacher tries to propose methodologies alternative to the text book, he/she finds it difficult because students are not used to them.
The teacher thinks that many young people quit learning chemistry and, in general, scientific studies after upper secondary school because they don't reach a significant knowledge, they merely memorize information and they convince themselves they don’t understand chemistry.
Another reason is that teachers don't use labs enough.
Granting more lab activities and proposing problematic situations to be solved, in order to increase motivation might help students to take up scientific studies.
The misconception that opposes “chemical” (negative) to “natural” (positive) should also be overcome.
She knows some initiatives in the field of promoting lifelong learning: PLS (project for scientific degrees) by the University of Genoa. She has no suggestion.

- Teacher 6 (Maths and Sciences at lower secondary school)

The teacher thinks that the reasons for major difficulties in learning chemistry at school are that students find cognitive obstacles because the contents are too “high”. Her main difficulty in teaching is to supply students with an adequate microscopic model of matter.

The teacher thinks that many young people quit learning chemistry and, in general, scientific studies after upper secondary school because of upper secondary school teachers: students don't understand and start being afraid of the subjects. Furthermore employment itself requires other professional profiles: if secondary school teachers did a better job, there would be no need of motivating students towards scientific universities.

She knows some initiatives in the field of promoting lifelong learning: some “open days” held by universities.

She has no suggestion.

- Teacher 7 (Chemistry at upper secondary school)

The teacher thinks that the reasons for major difficulties in learning chemistry at school is the lack of specific tools (basic abilities) for students. His main difficulties in teaching are the lack of labs and few lessons per week.

The teacher thinks that many young people quit learning chemistry and, in general, scientific studies after upper secondary school because they don't have interesting job offers. Increasing projects of scientific research at Universities and granting more job opportunities might help students to take up scientific studies.

He doesn't know any initiative in the field of promoting lifelong learning and he has no suggestion

- Teacher 8 (Chemistry at upper secondary school)

The teacher thinks that the reasons for major difficulties in learning chemistry at school are that students are not able to use their brains, they lack of basic requisites, especially in maths, they don't study enough. Her major difficulties in teaching chemistry is not to make the subject too abstract, but many schools don't have labs.

The teacher thinks that many young people quit learning chemistry and, in general, scientific studies after upper secondary school because, in order to attend a scientific faculty, students must be gifted, whilst in humanistic faculties studying is enough, even by heart. Making the access to employment easier might help students to take up scientific studies.

She doesn't know any initiative in the field of promoting lifelong learning and she has no suggestion.

- Teacher 9 (Chemistry at upper secondary school)

The teacher thinks that the reasons for major difficulties in learning chemistry at school are that students, at that age, don't have abstracting abilities and that many teachers are not able to teach. Her difficulty as a teacher are that it's necessary to make concepts easy but the risk is to make them banal too.

The teacher thinks that many young people quit learning chemistry and, in general, scientific studies after upper secondary school because those who teach scientific subjects can't do it properly. Proposing students more lab activities might help them to take up scientific studies.

She doesn't know any initiative in the field of promoting lifelong learning and she has no suggestion.

- Teacher 10 (Chemistry at upper secondary school)

The teacher we interviewed thinks that the reasons for major difficulties in learning chemistry at school lie in chemistry itself because it's a difficult-to-access subject, unless at a mnemonic and superficial level. Her main difficulty in teaching chemistry is to allow students to visualize what happens at microscopic level. Furthermore some concepts are difficult and even teachers don't have them clear in minds.

The teacher thinks that many young people quit learning chemistry and, in general, scientific studies after upper secondary school because they are not gifted for science. She doesn't know how to help students to take up scientific studies after upper secondary school because she thinks that first of all student must love the subject and each one should do what he/she feels like.

She doesn't know any initiative in the field of promoting lifelong learning and she has no suggestion

In short, some teachers seem to attribute students' learning problems in chemistry to the intrinsic difficulties of the subject (microscopic dimension, necessity of appealing to 'abstract' models, ...), others to scarcity of equipped labs, many to students' specific lacks (inadequate cognitive requisites, inability of abstracting, lack of interest in studying). Teachers' statements related to teaching difficulties and students' learning problems are summarized in Table 1, where it can be noticed the coincidence of teachers' and students'

difficulties in approaching this discipline. The most mentioned barrier is linked to the perception of chemistry at microscopic level.

Some teachers (probably not graduated in chemistry) think that also their personal knowledge of chemistry, not sufficiently deep, may contribute to creating obstacles for students.

Table 1. Teaching-learning process: difficulties in teachers' opinion

Teachers' difficulties in teaching chemistry	*Number of concordant opinions*	*Students' difficulties in learning chemistry*	*Number of concordant opinions*
not adequate teachers' skills	4	not adequate teachers' skills	3
difficulties in teaching at a microscopic (abstract) level	4	difficulties in the comprehension of the microscopic (abstract) level	6
not adequate books	2	not adequate books	1
lack of experimental activities	4	students' specific lacks	3
insufficient allocated teaching time	1		

A possible remark could be that the teachers interviewed have never seriously questioned themselves about the points dealt with in the questionnaire, as a deeper consideration of the matter should have made them reconsider their ways of forwarding concepts and information and realize how, very often, they themselves don't really understand what they are trying to communicate.

Maybe the problem lies also on their professional training, as evidenced by Fig.2: among them, only the 'younger' ones (not considering their age but their shorter experience in schools) have attended courses specifically concerning chemistry teaching.

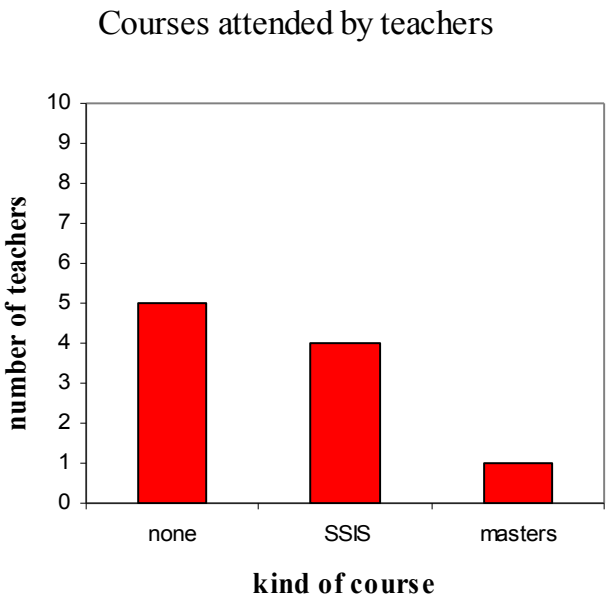

Fig.2. Courses on chemistry teaching attended by the ten teachers interviewed

None of them seems having heard about research activities or initiatives dealing with 'lifelong learning' of scientific subjects. Some of them report about projects of vocational guidance for students between secondary school and university, though they don't highlight any meaningful relapse.

Considerations on the national scenario

The interviews, the collection of many papers and reports dealing with the lifelong learning of scientific disciplines and the analysis of many initiatives aiming at encouraging a scientific lifelong learning for the citizens, led to formulate few considerations about the national scenario (University of Genoa 2010)

The numerous initiatives (museums, festivals, popular scientific press and TV programs, …) carried out at local and national levels, though positive because aimed at awakening public opinion and bringing people nearer to the world of research and science, don't seem to reach significant and long lasting results. Indeed, science is still perceived by many people as hard, difficult to access, abstract, far from everyday life. Moreover, chemistry has an undeserved negative halo: it's often associated to problems such as pollution and drugs and opposed to "natural", usually considered, on the contrary, as a synonym for healthy, authentic, genuine, better. This result can be explained observing that these initiatives can't make up for a possible lack of cognitive tools, abilities and competences that must be pursued at school; scientific popularization is often considered a valid substitute for didactic, but many are the

reasons why it can't be completely effective as the fact that every message addressed to an inhomogeneous public, carries inevitable problems linked to its intelligibility, because every receiver has a different cognitive background.

On the other hand, the situation at schools of each order and level is not better, despite many initiatives and projects dedicated to improve teacher training as well as student's interest and motivation, as the noteworthy 'Scientific Degrees Project' (PLS) (MIUR 2007) and the 'Teaching Experimental Sciences' project (ISS) (MIUR 2010). Students continue to consider chemistry as one of the most difficult disciplines, suffer from the lack of laboratories and practical activities and are not able to perceive the connection between the microscopic models described by textbooks and the macroscopic world of everyday life.

Finally, but not less important, teachers are not provided with suitable courses for initial and in service training. In 1999, for the first time, a post-degree two-year master (Training Course for Secondary School Teaching - *Scuola di Specializzazione all'Insegnamento Secondario* – SSIS) was instituted as a pre-service education for secondary school teachers, and was specific for different disciplines, including chemistry (Italian Chemistry Society 2005, Ostinelli 2009). In 2008 SSIS was interrupted and only in 2012 it was re-established, as one-year course, named TFA (Active Formative Training - *Tirocinio Formativo Attivo*). No other kinds of teacher training at national level are actually available for secondary school teachers.

Conclusions and strategy proposal

Every cultural, economic and political aspect of society is concerned with scientific issues, more or less "accessible" for the so called "common people", who are daily asked to make choices with heavy consequences on the health of individuals, community and environment.

From this point of view, a basic scientific knowledge is a necessary condition for such choices to be as rational as possible rather than emotional, autonomous rather than easy to be manipulated and orientated from outside.

But how can the adult citizen be made aware and responsible on these themes?

The information given by the media may be correct and accurate, but the easiness of information finding, granted by the spreading of technologies and the internet, sometimes only consolidate some spontaneous beliefs: inserting keywords in a search engine immediately gives a set of more or less concordant answers but, in order to evaluate the quality of a piece of information, it's necessary to possess some previous knowledge.

We think that the basis of a scientific culture should be built up starting from primary education with a methodology that aims, from the beginning, at developing cross-curricular abilities as opposed to a mnemonic and superficial knowledge of notions.

We can represent the possible interaction among children, students, parents, teachers and adults in general, by using the following diagram (Fig.3) where the arrows show the direction of interaction.

We believe that children must be introduced to Science by using a phenomenological approach. In this way not only it will be possible to stimulate their curiosity but at the same time work will be done at a level adequate to their cognitive structure.

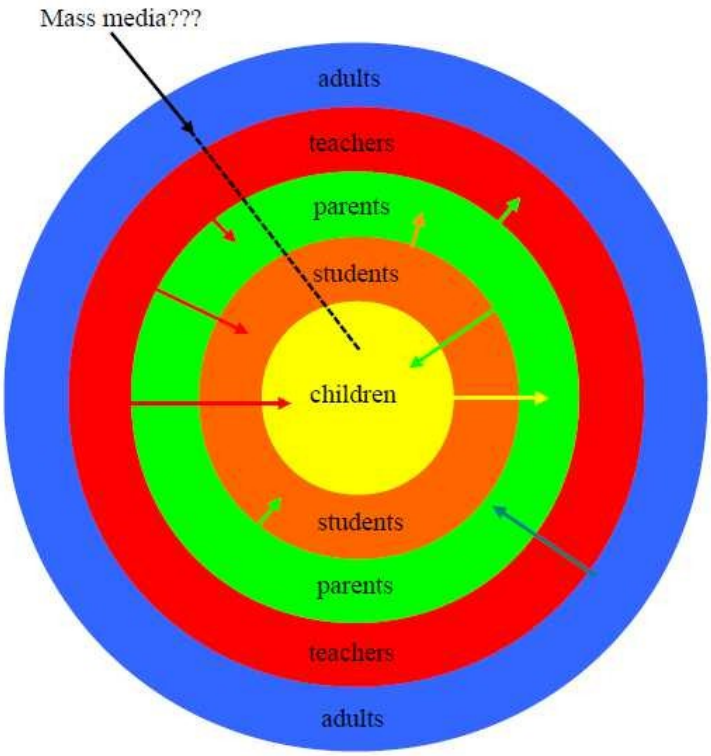

Fig.3. Diagram representing the possible interaction among children, students, parents, teachers and adults

Allow children to observe phenomena, describe their observations in sequence, work systematically to understand the significance of terminology and construct a shared definition are activities which, carried out individually or in groups, aid in the acquisition of transferable skills. These are skills that are acquired gradually in the successive educational levels and lead to the development of the logical and cognitive capacities that allow cognitive independence

and a critical spirit. Children, shown in the center of the diagram, are the most important category. If children are helped to approach science, chemistry in particular, as a part of their everyday life, they will be able to gradually understand all the rules and laws that belong to our knowledge, thus understanding that science needs to use models that may possibly change when better ones are discovered.

The motivation of children will subsequently be transmitted to their parents, who will be stimulated to share the scientific growth of their sons and daughters. We think that all activities involving both parents and children are very effective, but only if carried out by teachers able to involve both generations in a guided learning path based on a phenomenological approach. If parents change their ideas about Science, they will be able to fight prejudices that characterize their society and will be able to influence the adults close to them: in this way it will be possible to effect a change of the general perception of sciences. The weak point is that organisers specialized in education are not always involved in the events.

The diagram can be summarized as follows:

- children feel the influence of their parents and their teachers, but are little influenced by the adult population in general;
- parents influence children and teachers and are in turn influenced by them both
- teachers influence parents and children, but are conditioned by the expectations of parents
- adults, in general, can influence parents but are not influenced by the categories reported in the inner circles; on the other hand they are influenced by other entities, such as the mass media and the popular beliefs (even if the mass media influence everybody, we think that their worst effects are on non-educated people).
- students are a particular case: they are influenced by all adults and have little possibility of change, in fact it is very difficult to modify their thoughts. This is well known by teachers that have more difficulties to revise wrong concept than introduce a new one; students grow fond of these mistakes also during their higher studies, as it is possible to verify even in teacher training trials.

What can be concluded? The only possibility of modifying the way of thinking of our European society is to train expert teachers and follow them throughout their professional lives according to a lifelong learning approach to in-service teachers training. For this reason, the presence of an organisation generously funded by the government with the aim of carrying out didactic research is fundamental. Universities are the best organizations capable of this: not only the Faculty of Education, but all scientific faculties should have research teams,

collaborating with their colleagues of Science of Education to study the best ways of teaching scientific subjects at all age levels. To the same end, it is necessary to address scientific dissemination in order to avoid misleading information diffused by the mass media.

On top of that, we need more interaction between universities and schools, especially in the training of science teachers. University lecturers and experts must go into schools and accompany/watch/ask teachers and students at school to get to know what's going on.

Future perspectives

On the light of the results collected on the CIAAU portal, the European Commission decided to fund another Project: 'Chemistry Is All Around Network' (CIAA_NET, **http://chemistrynetwork.eu/**).

CIAA_NET is a three years project funded in the framework of the Lifelong Learning Programme – Comenius sub programme – Networks Action, aiming at stimulating the interest of students towards the study of chemistry.

The specific aims of the 'Chemistry Is All Around Network' are:

- Enhance the interest for chemistry, by sharing the most effective strategies for learning and teaching this subject.
- Present chemistry under a renewed and positive attitude, by giving evidence to how it affects everyday life and how it can contribute to the explanation of many everyday phenomena.
- Improve science teaching methodologies through the cooperation between teachers and experts.
- Create a Network among educational institutions for the exchange and comparison of experiences in order to fill in the gap between the world of scientists and school teachers.

The project involves thirteen partners from eleven different Countries (Belgium, Bulgaria, Czech Republic, Greece, Italy, Ireland, Poland, Portugal, Slovak Republic, Spain, Turkey), sharing experiences and information in the common effort of promoting the learning of chemistry. It is based on the collaboration of school teachers, scientific experts and university researchers and foresees different activities in order to fulfil the above aims. Research activities, collection of teaching resources, organization of national and transnational meetings, organization of international conferences will be carried out according with the three area of interest of the project: 1. students' motivation; 2. teachers' training; 3. successful experiences and good practices.

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