Successful experiences and development of key competences in chemistry education: the Italian context

Laura Ricco, **Maria Maddalena Carnasciali**
Department of Chemistry and Industrial Chemistry – University of Genoa, Genoa – Italy
marilena@chimica.unige.it

Abstract

As often teachers underline, textbooks are an essential tool and a good point of reference for students, but they are not sufficient to teach chemistry in a significant way. For this reason, teachers often look for sources from which to get updates on scientific knowledge, but also on teaching methodologies and on successful experiences. These considerations became even more valuable in 2012, when the New National Guidelines of the Italian school system established the framework of key competences for lifelong learning, defined by the European Parliament, as the reference horizon to work towards.

The teaching for competences made essential to renew the teaching of disciplines, especially of sciences, away from the previous transmissive teaching and focusing on the action" in situation" of the student.

The "Chemistry Is All Around Network" project is working to help teachers to update their teaching methodology. The project portal has a database of successful experiences to teach chemistry and provides numerous digital teaching resources, some of them tested in classroom. As an example, the testing of a site dedicated to the periodic table of elements, performed involving 200 students of secondary school, is reported in the second part of this paper.

1. Competences in the European context

In 2000, the European Union started a process well known as the *Lisbon Strategy* [1]. It is a system of reforms that spans all fields of economic policy, but its main characteristic is that for the first time the themes of knowledge are identified as fundamental.

In the conclusions to the work of Lisbon 2000, future ways forward in the field of education were recommended to the member states: among these, there was the indication to get to a definition of key competencies for the exercise of active citizenship.

Subsequently, in 2006, the European Parliament and the Council invited the Member States to develop, as part of their educational policies, strategies aimed to grow in young students the eight key competences that may constitute a basis for further learning and a solid preparation for adult and working life [2].

The eight key competences are:

1. Communication in the mother tongue
2. Communication in foreign languages
3. Mathematical competence and basic competences in science and technology
4. Digital competence
5. Learning to learn
6. Social and civic competences
7. Sense of initiative and entrepreneurship
8. Cultural awareness and expression

In the next document, called *European Qualifications Framework* [3] for the lifelong learning, the European Parliament defined with precision the concepts of knowledge, skills and competence:

- Knowledge means the outcome of the assimilation of information through learning.Knowledge is the body of facts, principles, theories and practices that is related to a field of work or study. In

Lifelong Learning Programme

This project has been funded with support from the European Union.
This material reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

the context of the *European Qualifications Framework*, knowledge is described as theoretical and/or factual.

- Skills means the ability to apply knowledge and use know-how to complete tasks and solve problems. In the context of the European Qualifications Framework, skills are described as cognitive (involving the use of logical, intuitive and creative thinking) or practical (involving manual dexterity and the use of methods, materials, tools and instruments).
- Competence means the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development. In the context of the European Qualifications Framework, competence is described in terms of responsibility and autonomy.

2. Competences in the Italian context

The concept of competence came in the Italian school from 2000 (Berlinguer - De Mauro reform), and was finally "coded" by DM n. 139 of 22 August 2007, which introduced new guidelines for the second cycle and compulsory education up to sixteen years.
The *New National Guidelines* for the first cycle of education (primary school and lower secondary school) of September 2012 [4] expressed more clearly that the Italian school system takes, as reference horizon to work towards, a framework of eight key competences for lifelong learning defined by the European Parliament and the Council of the European Union [2]
The text of the *New National Guidelines* expresses a general goal, the *competence profile of the student* at the end of the first cycle of education, which clearly takes its cue from the eight key competences and inserts them within the curriculum of the Italian school.
After defining the *profile of the student*, the *Guidelines* talk about disciplines, which aim at the achievement of *goals for the development of competences*, fundamental references for teachers.
In the case of sciences, the goals that the student has to attain at the end of lower secondary school are expressed globally for chemistry, physics, biology, astronomy and earth science [5]:

- the student explores and experiments, in the laboratory and outdoors, the unfolding of the most common phenomena, imagines and tests the causes, researches solutions to problems using the knowledge acquired;
- he develops simple schematization and modeling of facts and phenomena using, when appropriate, to take suitable measures and simple formalization;
- he recognizes in his body structure and operations at macroscopic and microscopic levels, is aware of his potential and limitations;
- he has a view of the complexity of the system of the living and of the evolution over time, recognizes their diversity, the basic needs of animals and plants and ways to meet them in specific environmental contexts;
- he is aware of the role of the human community on Earth and adopts environmentally responsible way of life;
- he links the development of science to the development of human history;
- has curiosity and interest towards the main problems related to the use of science in the field of scientific and technological development.

The *New National Guidelines* gave precise instructions for the reorganization of the first cycle of education. At the same time and consistently, MIUR (Ministry of Education, University and Research) worked to conform to the European guidelines also the organization of upper secondary school, by issuing guidelines for the second cycle of education [6]: therefore, the didactic at the lyceum, at the technical and vocational school underwent a change and was focused on the development of key competences.
In this new scenario, teachers and educational institutions were asked to change their working method. Now, the keywords are: design, formulate curricula in a lifelong learning perspective and certify competences. A no easy task to perform.

Lifelong Learning Programme
This project has been funded with support from the European Union.
This material reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

3. Successful experiences in chemistry teaching

The teaching for competences made essential to renew the teaching of disciplines, especially the sciences, away from the previous transmissive teaching and focusing on the action in situation of the student.
Competence in science and competence in technology are the key competences more linked with the study of chemistry. Competence in science refers to the ability and willingness to use the body of knowledge and methodology employed to explain the natural world, in order to identify questions and to draw evidence-based conclusions. Competence in technology is viewed as the application of that knowledge and methodology in response to perceived human wants or needs. Competence in science and technology involves an understanding of the changes caused by human activity and responsibility as an individual citizen" [2].
In this context, teachers are encouraged to teach using a laboratory approach and are often looking for successful experiences suitable to stimulate the active role of their students.
The teachers involved in the project were interviewed and stated that the search for such tools consists almost always in consulting Internet by keywords: this is obviously risky and dispersive, because on internet you can find everything, but not everything is to be considered valuable. Sites or portals dedicated to providing educational material, proven and certified by experts, are rare and certainly not well disseminated.
The most cited site belongs to the publisher *Zanichelli*. The textbooks by Zanichelli are the most common in Italian schools of each grade. The site [7] gives access to useful material such as concept maps, power point lessons, interactive questionnaires for students, videos and more.
There are also sites of universities and schools that provide educational materials performed or used by their teachers.
The site of the national project *PLS (Scientific Degrees Plan)* is strongly recommended by the MIUR: at the project site [8] you can access to several successful experiences, designed and carried out by universities for secondary schools.
Good sources to address scientific issues at school are also some magazines (also available in digital format), such as:

- *Le Scienze*: is a monthly magazine devoted to scientific popularization. It is the Italian edition of Scientific American. In addition to basic science, it pays particular attention to the impact of science and technology to technical progress [9].
- *Linx Magazine* - the magazine of science for class: it is addressed to teachers and dedicated to the teaching of the sciences. It provides insights, updates, practical learning activities, exercises and questionnaires for students [10].
- *Nuova secondaria*: is a magazine dedicated to the cultural and professional training of teachers and school leaders of secondary school. It provides didactic disciplinary paths, inserts that in each issue deal with a multidisciplinary theme, discussions focused on "cases" of legislation, critical presentations about educational policies and professional culture [11].
- *CnS – La Chimica nella Scuola*: is a national reference point for researchers in education and many chemistry teachers that can find important insights for educational activities, numerous successful experiences described in detail and possibility of update [12].

The Ministry of Education also strongly encourages the use of digital resources in the teaching of disciplines, with the aim of developing a transversal key competence: the digital competence involves the confident and critical use of Information SocietyTechnology (IST) for work, leisure and communication [2].

4. The contribution of the project *Chemistry Is All Around Network*

The *Chemistry Is All Around the Network* project worked, and still works, intensely to select digital resources for teaching chemistry that are really useful for learning. The project portal provides a rich database of digital resources selected by teachers and experts involved. Some of these resources were tested in classroom and useful reports were produced: they contain testimonials and suggestions for educational paths that can be performed and supported by the above tools, tips and considerations from teachers.

Lifelong Learning Programme
This project has been funded with support from the European Union.
This material reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

PhET Interactive Simulations [13] is a site known by many teachers. It provides a number of simulations for different scientific disciplines and is appreciated for the richness and simplicity of these simulations that have been translated into several languages, including Italian.
Simulations, as well as other digital resources, are tools that allow students to take an active role and allow teachers to build useful exercises to experiment, investigate, verify science contents that, otherwise, can be perceived as abstract and difficult to understand.
In order to use digital tools as successful experiences, especially in the context of competence development, it is necessary a suitable design. This means that digital resources have to be inserted properly and significantly in educational paths, where the interaction between teacher and student and among students themselves cannot miss, and where practical experience needs to be included, carried out in the classroom or in the laboratory, but, in any case, real. Many teachers however, especially if no more young, claim low affinity toward ICT resources and feel compelled to include them in their teaching, threatening to use them badly, such as tools detached and left to the autonomy of students. The first step is to break down this distrust, by encouraging the use of simple digital tools that meet the favor of students and not embarrass teachers. A serene atmosphere is essential as the work of design-action-evaluation leads to significant learning experiences, especially when new methods are tested.
On this basis, we selected a digital resource from the database of *Chemistry Is All Around Network*: the site *tavolaperiodica.it* [14] seemed to us the most suitable to be presented at schools for demonstration purposes. The site does not require any computer skills to be used, it is not dispersive, deals with the chemical and physical characteristics of many elements through photos, videos of reactions and properties, explanatory texts suitable for upper secondary school students. It is not an interactive periodic table and is composed by sections, each one dedicated to a group of elements: alkali metals, alkaline earth metals, transition metals, lanthanides, the group of boron, carbon, nitrogen, oxygen, halogens. By selecting contents and sections, it can be used at lower secondary school.
In this way, teachers could have an example of how a digital resource, although very simple, can be used to enhance learning of curricular chemistry contents.
A short two-hour path was designed around *tavolaperiodica.it* and proposed to 10 classes of upper secondary school (about 200 students) who had started to study the periodic table of elements. The path was carried out entirely in the computer lab; during the first thirty minutes students, in small groups, surfed autonomously within the site, while, for the remaining time, they were involved in a non-traditional lesson. During the lesson, the virtual laboratory was joined to practice, observation and guided discussion, in order to connect previous knowledge to the new context, to consolidate and deepen.
The videos of some chemical reactions, dangerous to be really carried out, as the reaction between the alkali metals and the water or the burning of calcium, were used to guide students to the construction of the corresponding equations (What did you see? Which are the reactants? And the products? What is burning?)
The transition from the phenomenon to the symbolism and vice versa is anything but simple for students. In fact they are used to write chemical equations and to do calculations about them, but without connections to real phenomena; we know that contextualization is important to better understand the chemistry and the significance of the models that chemistry uses.
Although the virtual laboratory is useful because allows to observe reactions and phenomena dangerous or expensive to carry out, it must be joined to the real laboratory, that is to practical experiences that enable students to touch and <u>to do by themselves</u>. For this reason, short demonstrations were performed to supplement the contents of the site, several samples of substances were made available to students, observations were stimulated and questions were asked.
For example, the reaction of burning magnesium, performed in the video with a large amount of material, was repeated in the classroom with a small piece of magnesium: the light produced was still very intense, and the discussion was focused on the different ways in which energy can manifest itself (heat, light, flame etc.).
Another example: a piece of zinc was dipped in a solution of $CuSO_4$. The change of color, from gray to red, was used to deduce the reaction products, then the corresponding equation was written. Even in this case, the practical activity was compared with a video, where a solution of $CuSO_4$ reacts with an iron nail and, in

time, decolorizes completely in correspondence to the deposition of metallic copper on the nail. On the initiative of some students, connections to redox reactions and to batteries were made.
Talking about carbon, a sample of charcoal was shown and its bleaching properties were demonstrated by filtering water containing food dye. Charcoal is widely used in filtering carafes, filters for pools, purifiers, deodorizers and is also sold in pharmacies, so this experiment is used to connect chemistry to everyday experience, highlighting how the study of materials and their properties has important consequences, very different and sometimes unthinkable, on society.
Numerous samples of simple substances (lead, zinc, copper, mercury, gallium, silicon, sulfur, tin, tungsten, iodine, etc.) were given to students for the purpose of identifying them by using personal experience, but also photos and information from the site. This simple "game", which combines real and virtual, raises motivation without placing the student in trouble and predisposes to numerous in-depth as a function of the questions / curiosity that inevitably arise. It may be organized in different ways depending on the sensitivity of the teacher and of the class: samples of alloys can be added, or objects of common use, then asking to identify which elements are present.
Finally, samples of compounds were shown to discuss how radically physical properties, but also chemical properties, change if compared to the elemental state (eg Cu in comparison with $CuSO_4$, CuO, $CuCl_2$).
The site also provides historical notes, anecdotes and references to specific applications: depending on the interest expressed by students, some of this contents were investigated. For example, the discovery of the dangerous white phosphorus, whose combustion is shown in a video, led to talk of how man invented matches, but also chemical weapons, sadly still current, raising in students the awareness on the importance of ethics in science.
As it can be deduced by the brief description above, the didactic path was designed aiming to competence development: the active role of students was stimulated as much as possible, referring to their life experience and scientific knowledge. The structure of the lesson has been the same for all classes, but without excessive stiffness: we took care to leave enough space to changes / insights due to curiosity or perplexities, different from time to time.
Eventually, students developed, briefly and in writing, the following theme: "You have just experienced a new way to learn and study chemistry. If you approve it, try to give 5 tips to convince your teacher to use it with your class, if you do not approve, explains why "
Student assessment has been very positive: they stated to feel more involved and motivated than during a traditional lesson. They liked the virtual experiences, that cannot be repeated in the laboratory, and the real ones, emphasizing the importance of contact with what is being studied. This confirms that the so-called “traditional lesson” is to be abandoned, not only because it is not suitable to develop competences, but also because young people are no longer able to learn by following long explanations, indeed they need to receive stimuli, to feel active and find correspondence between what they study and their lives.
Concerning teachers, even the most skeptical recognized the usefulness of a digital tool, when well integrated into a meaningful learning path, where real and virtual can interact and complement each other.
As already underlined, *tavolaperiodica.it* is the most simple example to start using digital resources in the classroom; with time, practice, collaboration with colleagues and further training, it is possible to access more complex instruments, and planning a use proper to the development of scientific and digital competences of highest level.

5. Conclusions

The education reform started by the *Lisbon Strategy*, got positive answer in Italy, where the whole school system was reformed on the basis of a didactic for competences.
However, this change caused difficulties to teachers, who had to abandon traditional teaching methods in favor of a new design of the curriculum. In this context, research and / or construction of successful experiences is much more felt than once.
The *Chemistry Is All Around Network* project has been an important stimulus to research and select, along with experts and teachers, useful material for the new chemistry education, starting from the foundations,

This project has been funded with support from the European Union.
This material reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

that is from primary school, to secondary school. It is essential that the approach to science, even more chemistry, takes place in the early years of school, when the child is curious and observant to everything around him. Look carefully and try to design around what nature daily offers, stimulates the mind that, if properly guided, can be arranged to process scientifically each event and any information it receives. At this level, the study of chemistry will no longer be tiring, but exciting.
The project was not only a work of selection, because it gave rise to motivation and opportunity to build well-designed educational paths that, with testing and evaluation over time, can develop and become successful experiences available to all.

Acknowledgements
The authors thank the Lifelong Learning Programme – Comenius Sub Programme, of the European Union for financial assistance.

6. References

[1] http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/00100-r1.en0.htm
[2] http://www.britishcouncil.org/sites/britishcouncil.uk2/files/youth-in-action-keycomp-en.pdf
[3] http://europa.eu/legislation_summaries/internal_market/living_and_working_in_the_internal_market/c11104_en.htm
[4] http://www.indicazioninazionali.it/J/
[5] http://media.pearsonitalia.it/0.077321_1363012055.pdf
[6] http://archivio.pubblica.istruzione.it/riforma_superiori/nuovesuperiori/index.html
[7] http://www.zanichelli.it/home/
[8] http://www.progettolaureescientifiche.eu/
[9] http://www.lescienze.it/
[10] http://magazine.linxedizioni.it/
[11] http://nuovasecondaria.lascuola.it/
[12] http://www.soc.chim.it/divisioni/didattica/cns
[13] https://phet.colorado.edu/it/
[14] www.tavolaperiodica.it