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Successful Experiences in Chemistry Teaching in Italy

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SUCCESSFUL EXPERIENCES IN CHEMISTRY TEACHING IN ITALY

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Abstract

The national report on successful experiences in chemistry teaching focuses mainly on the presentation of seven valuable experiences performed in Italian schools and on the description of the testing carried out to further enhance the database of ICT resources available on the project portal of Chemistry Is All Around Network.
The seven successful experiences are based on the laboratory approach, that is the action of the student in situation and comply with the New National Guidelines 2012 for the Italian school system, which outline a teaching based on the development of competences.
According with the aim of competence development, seven ICT resources were tested in classroom by the teachers involved in the project: a description of how they were used and the evaluation of the results obtained are reported in this paper and, more in detail, in the project portal .

1. Introduction

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 that can help the learning. These considerations became even more valuable in 2012, when the New National Guidelines of the Italian school system [1] (see section 3) 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 the sciences, away from the previous transmissive teaching and focusing on the action in situation of the student. 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 [2] 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.

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For what concerns ICT resources, the site *PhET Interactive Simulations* [3], a project at the University of Colorado Boulder, provides several simulations, even in Italian: this site is known and used by science teachers who want to include digital resources in their teaching methodology.
Finally, talking about successful experiences provided online, the site of the national project *PLS (Scientific Degrees Plan)* is strongly recommended by the Ministry of Education (MIUR). The PLS has often been presented and described in the activities of *Chemistry Is All Around Network* therefore, for more details, please refer to the documents previously provided [4] and to the project site [5] where a number of successful experiences, designed and carried out by universities for secondary schools throughout Italy, are accessible.
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 [6].
- *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 [7].
- *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 [8].
- *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 [9].
- 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 [10].

2. Key competences and their development in chemistry education

The concept of competence comes in the Italian school from 2000 (Berlinguer - De Mauro reform), and is finally "coded" by DM n. 139 of 22 August 2007, which introduces New National Guidelines for the second cycle and compulsory education up to sixteen years.
The New National Guidelines of September 2012 [1] 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 [10].
Competences are defined as a combination of knowledge, skills and attitudes appropriate to the context. Key competences are those which all persons need for personal fulfillment and development, active citizenship, social inclusion and employment:

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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

Starting from the 2012-2013 school year, primary and lower secondary schools (first cycle of education) rework the training offer, taking as reference the New National Guidelines. The teaching for competences is thus officially introduced also in primary and secondary school.

Accordingly, the objective of the first cycle of education becomes the achievement of goals for the development of key competencies, goals clearly stated for each discipline, in the New National Guidelines.

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 [11]:

- 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.

In order to help schools to conform the chemistry/science curriculo to the New National Guidelines, the Didactic Division of the Italian Society of Chemistry provides a proposal for primary [12] and lower secondary schools [13].

The study of chemistry during the upper secondary school, as starts from the above-mentioned goals of learning, aims at continuing the development of key competencies, *in primis* the competence in science and technology. “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

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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" [10].

3. Examples of successful experiences

3.1 First approach to the periodic table of elements. A historical-epistemological approach to the teaching of chemistry [14]

Authors**:** *Alberto Regis, Ezio Roletto*

Experience description

It is frequently suggested that the history of chemistry can be used in teaching the subject on the account of supposed parallels between the learning process and the development of science. This idea is put into practice in the teaching sequence described in this paper, aimed at bringing high school students to build up the foundations of the periodic table of the elements. Learning situations are based on thought provoking problems concerning the macroscopic properties of simple substances: to answer these questions, students may refer to the same information used by Mendeleev to build up the principle of periodicity. The learning situations bring the students to deal also with two important chemical concepts: those of simple substance and element which are frequently confused in teaching.

The sequence presented in this article has been tested over several years in several classes and essentially aims to bring students to "rebuild" the backbone of the periodic table, reasoning on the same chemical information that was available to Mendeleev: the atomic weights of the elements and the physical and chemical properties of some simple substances and compounds. The historical approach has the advantage of making students retrace the intellectual path of Mendeleev, highlighting the difficulties and the various hypotheses that were subsequently deemed acceptable or rejected.

As a first activity, each student is provided with a sheet of paper format A21 and a set of nineteen cards on the following elements: potassium, hydrogen, lithium, boron, beryllium, magnesium, aluminum, bromine, chlorine, sulfur, sodium, calcium, silicon, oxygen, fluorine, arsenic, carbon, nitrogen, phosphorus. Then, the following delivery is assigned: "order, in the way you think more appropriate, the cards you received, pasting them on the sheet of paper. On the same sheet, write, in order of importance, the criteria used to order the cards".

The subsequent activities, which are described in detail in the publication, aim to improve the first draft of the periodic table built by the students, using new information, the guidance of the teacher, the work in small groups and the comparison between the different views.

Finally, the inclusion of new elements in this periodic table leads to verify the criterion used to sort the elements and to discover the concept of periodicity.

Experience assessment

The approach described in the paper was readily accepted by most of the students, who become involved by problematic questions which require them to think, reflect, reason, make predictions and draw conclusions.

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Offering students the opportunity to work in first person to the development of the structure of the periodic table, as Mendeleev did, allowed them to build the concept of periodicity in the operating mode, as a result of a personal path to the knowledge.

From the point of view of science education, the historical setting is much more educational than the traditional one, in which knowledge is systematized and where you forget all the attempts of other scientists, the different approaches and the first inconsistencies.

The specific disciplinary knowledge and the learning objectives have been achieved in a satisfactory way.

3.2 Growing in European dimension [15]

Author: *Nadia Zamboni*

Experience description

The article is the description of how an ICT resource in English was used to teach chemistry at lower secondary school. The teacher, Nadia Zamboni, used it to experience the CLIL methodology in building science and digital skills. The whiteboard gave an essential support because it favored the cooperative work, through continuous sharing moments between groups of pupils.

Chemistry at home, the interactive section of the site Chemistry Is All Around Us, provided interesting insights to undertake, with laboratorial approach, a path of observation and reflection on a common chemical reaction such as that between vinegar and baking soda. The students, divided into groups, have explored part of the resource, focusing on the reaction and collecting information on some factors affecting it. The English texts have also allowed an unusual approach to the specific terminology in a foreign language, which has become part of the learning process. Each group, after choosing an experimental variable to be tested among quantity, temperature and concentration of reactants, presented the activity to the other schoolmates, in the form of self-managed project. At the end of the activity, the teacher required a scientific report including both the work done in the first person and the one made by the other groups. The activities were also supported by the implementation of worksheets in Italian / English, provided by Nadia Zamboni and compiled by the students, again through a mode of cooperation extended to the entire class. The details of the work, carried out with a second class of lower secondary school degree, were recently published online and are freely available.

Experience assessment

The article is important because it describes a successful experience carried out as part of this project (Chemistry Is All Around the Network), taking advantage of one of the tools provided by the previous project "Chemistry Is All Around Us. The educational activities built in this way underline the effectiveness of the efforts made by the countries participating in the projects and demonstrate the interest of schools and teachers to new teaching methodologies, whether under the guidance of researchers and experts.

The work described was carried out by the teacher of an associated school, which is involved in educational projects and agrees in working not only in a national but also in a European dimension. For a teacher it is definitely difficult to take courses using new teaching methods, especially when he/she did not received the necessary training. However, the article shows that the support of selected material and the guidance of

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experienced people (people involved in the project), make this task easier and the chances of success increase.

Moreover, the use that the author made of the ICT resource, shows that it is possible, and useful, to work siding different methodologies (as in this case: work in groups, practical activities and digital resources). The result is the improving of the learning, due to a good student motivation and to the satisfaction of the different learning styles.

3.3 Introduction to carbohydrates in upper secondary school: 1. a laboratory path inspired by everyday life [16]

Authors**:** *Maria Maddalena Carnasciali, Laura Ricco, Alessandra Minguzzi*

Experience description

The laboratory path, constituted by 6 activities, has been designed within the Scientific Degrees Plan – Chemistry Area – Liguria Region. Carbohydrates have been chosen as a subject of the path, proposed to the fourth year of upper secondary school, so as to reconcile the skills of teachers, mostly biological, with a chemistry topic curricular and suitable for interdisciplinary connections.

Moreover, the presence of carbohydrates in the daily life is likely to provide many opportunities for practical activities, appropriate to arouse curiosity and interest in the students and educational integration by teachers.

The paper proposes a sequence of 6 experiences linked with the process of bread making.

Activity 1) Filling in a table relative to the generality of certain carbohydrates of common use, assisted by 'taste' and solubility tests;

Activity 2) Bread making with different types of flour and yeast and construction of the leavening curve;

Activity 3) Separation of gluten and starch from a mixture of water and wheat flour;

Activity 4) Colorimetric test for the evaluation of the presence of starch in foods;

Activity 5) Colorimetric test for the evaluation of the presence of proteins in foods;

Activity 6) Application of colorimetric tests to analyze the two components separated during the activity 3.

In order to make more effective the sequence of experiences, the scientific report has to be required, of course after an exhaustive discussion of actions, observations and results carried out in the classroom, under the guidance of the teacher and as conclusion of the path.

Each experience is described in detail, as well as the related considerations made on the basis of students' behavior and learning. Moreover, the paper provides all the laboratory sheets, complete with information about the topics, detailed instruction about how to work and questions to be answered.

Experience assessment

The laboratory path had a huge success because it was carried out in many classes of scientific and classic licei, for a total of about 800 students. The laboratory activities were carried out by university researchers while the task of teachers was to introduce biochemistry before the foreseen practical activities, discuss the results in conclusion and correct the scientific reports written by students.

This path had a great success, as because students worked with motivation, as because teachers have received support and valuable material to improve itself in a field where they feel weak.

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3.4 Laboratory experiences to study gaseous substances at lower secondary school [17]

Authors**:** *Pierluigi Riani*

Experience description

An experimental work is presented, addressed to the acquisition of the concept of materiality of gases. The reference school level is the lower secondary school (pupils aged 11 – 14 years), but the work can be adapted to the last years of primary school and to the first years of upper secondary school. The experiments involve mainly the sensorial aspects. The article proposes a sequence of experiences made with materials that are easy to find and not expensive: mainly water, syringes, plastic cups and little more for further deepening. Below, a brief description of the sequence of activities is provided.

1. Air can be seen. This can be showed by emptying in a glass of water a syringe full of air.
2. Air can be touched: sensations caused by the flow of air on the palm of the hand.
3. The air can be poured: the experiment works underwater, with a glass upside down
4. The air exerts a thrust and is compressible: for this purpose, two syringes connected by a flexible tube are needed simply
5. Air occupies a space: this experience can be realized in two distinct levels, the first is purely qualitative, while the second is quantitative and needs to do measurements. The first case needs a jar with hermetic cap drilled in two points, two flexible plastic tubes and a small funnel. In the second case, more complex, the construction of a hydro pneumatic bathroom is required.

The sequence was proposed in some lower secondary schools and aroused interest of pupils, also because they were very glad of working with water. Main problems are linked to the need of keeping a suitable behavior: activities are not games but a way to learn. Times to carried out the whole sequence are long and, in order to obtain good results, it is needed not to hurry. The objective to be achieved is not the fulfilment of the experience, but its understanding and students generally have no need for a very short time, even if they work with commitment. Considering the large number of experiments, the teacher who wants to carry out them all and does not have the necessary time can share the tasks among the students; in this way they will have a practical demonstration of how scientific work is often a collective work, in which everyone uses the results obtained by others.

Experience assessment

The science textbooks for lower secondary school suggest, almost always, demonstrating the "materiality" of the gaseous state with the weighing. They proceed with a normal rubber balloon: first a deflated balloon is weighed, then it is swollen and weighted again. It is found that the weight is increased: the increase is thus due to the weight of the air. Unfortunately the weighing must be of high precision in order to have a reliable result; as it is well known, balances are not present at schools and when available, their precision is low. Moreover, the above demonstration is not sufficiently effective for young people and their idea of gas remains abstract and dangerously mnemonic. In order to get a significant learning of the concept of gaseous substance, it is necessary to follow a more “sensorial approach”, as the one described in the article: air can be seen, air can be touched, air can be decanted, air can exert a thrust.

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3.5 Olives in *salamoia* and fruit in syrup [18]

Authors**:** *Giuseppina Caviglia and Lia Zunino*

Experience description

The article shows the design and realization of an activity in science education carried out in two classes of primary school (third and fourth year). The theme, the acquisition of the concept of solid substance soluble in water, is about chemistry but the primary goal of the work is to develop first skills necessary for the study of experimental sciences.

The work with children started in a motivating context, the preparation of pickled olives. From this, the need to observe, describe, classify, discuss and formulate hypotheses, developed a further activity that helped to refine the language and to formulate, at the end of the long process of observation and research, a shared definition of soluble solid substance.

The paper describes the detailed sequence of activities carried out, the considerations of the two teachers step by step, the involvement of their little pupils and, eventually, the results in terms of learning and developments of skills.

Experience assessment

The points of strength of the work are the following:

- the teacher has a role of activator of processes;
- discussions allowed students to develop communication and argumentative skills;
- the request of designing, putting the kids in a position to do so autonomously, opens the door to the creativity of everyone, even the weakest;
- The work is developed in terms of observation and description of phenomena and not on their interpretative explanation. This setting is appropriate for a primary school, because an explanation would require the knowledge about the structure of matter that children of this age cannot control and understand but only "believe", trusting in the teacher or the textbook.

3.6 Toward a significant approach to scientific knowledge: an interdisciplinary proposal for primary school. [19]

Authors**:** *Aldo Borsese, Barbara Mallarino, Ilaria Rebella, Irene Parrachino*

Experience description

The authors of the publication belong to a research group composed by experts in chemistry teaching and primary school teachers. They planned and put into practice some interdisciplinary teaching proposals for primary schools,

focused on the chemical process of dissolution, using the group's own educational materials.

The educational paths are all based on laboratory teaching: the pupils observe and describe, formulate hypotheses,

plan and test, store and interpret the data they get. The definition of some scientific terms, cooperatively made up by the

class, represent the conceptual synthesis of the whole work.

The work is composed by more steps.

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During the first step, the group paid particular attention to the acquisition of lexical and conceptual requirements necessary for further work, arriving at the construction of a shared definition of "solid substance soluble in water" (i.e. "A solid substance is soluble in water, that dissolves in water, when ... no longer visible grains and the liquid is colorless transparent or colored transparent") until building, in later years, the concepts of conservation of mass, concentration and saturation.
In the second step, the acquired concepts were recovered and a deepening of the observed aspects was done ("The grains are not seen or are not there more? What can we do to determine this? How much salt can we dissolve in a glass of water? How can I do to produce a larger amount of solution with the same shade of color?") until arriving to the definition of “concentration” as ratio between non homogeneous quantities, by linking experiences carried out in different situations during all five years (measurements, decimals, fraction and percentage concept, intuitive concept of proportion).
Then, a conclusive discussion was carried out, aiming to remember what is a solution, as it is recognized, what solutions were prepared in the past and what features were identified.
It was followed by an individual production: "What determines the concentration of a solution?". The answers were shared and discussed.
Finally teachers proposed a task to verify the learning; the results were generally satisfactory: even children who had made mistakes, showed to have internalized many of the concepts discussed.

Experience assessment

This proposal is very significant as first approach to solubility concept and solutions. The children will improve their logical competences and their skills in self-evaluation, comparing their points of view with their classmates. They will also develop their linguistic and metacognitive abilities. The results obtained have proved the formative value of the methodology we are suggesting. We believe that a such careful planning of educational settings will stimulate and motivate students towards the development of cognitive autonomy.

3.7 Website of the Scientific Degrees Plan - area of chemistry - Liguria section [20]

Authors**:** *Maria Maddalena Carnasciali, Laura Ricco*

Experience description

This is the official website of the Scientific Degree Plan - Area of Chemistry - Liguria Section. It is powered by the Department of Chemistry and Industrial Chemistry (DCCI) of Genoa University.
The website is a reliable and rich source of successful experiences to teach chemistry at upper secondary school. The experiences proposed by the site were designed and carried out in several schools by researchers of the above Department.
The website is very useful because successful experiences are laboratoral paths and all needed tools to reply them are provided; in fact, detailed laboratory sheets are provided as well as power point presentations that teachers can use to introduce the different topics linked to the laboratory activities.
On the left side of the homepage there is the menu of the laboratorial paths available and widely experienced:

- laboratories with DCCI
- laboratories with enterprises

Laboratories with DCCI are four different paths dealing with:

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1. Interaction between light and matter
2. Pressure and temperature
3. Polymers and plastics
4. Carbohydrates and proteins

and were developed on the basis of interest and necessity expressed by teachers of schools involved in the project.

Laboratories with enterprises were developed in collaboration with enterprises located in Liguria Region and kindly available to show students the working reality of a chemist. The aim was to design and provide activities very similar to those carried out by chemist working in the above enterprises. The following paths are uploaded on the project website:

1. laboratory activities linked to Porto Petroli SpA (dealing with plastics)
2. laboratory activities linked to Acquarium of Genoa (dealing with water analysis and purification)
3. laboratory activities linked to Scientific Police of Genoa (dealing with forensic chemistry)
4. laboratory activities linked to Flli Parodi SpA (dealing with cosmetics and soaps)

Experience assessment

The Scientific Degrees Plan is, actually, the most active and widespread project at national level to improve the teaching of some scientific discipline at upper secondary school. It is financed from the Ministry of Education since the first edition, in 2005. The project was born to face the alarming decrease of enrolments to some scientific courses of degree, chemistry included; year by year, it realized a great success in improving the teaching-learning methodology in upper secondary school so as to become a reference point for many teachers.

Our institution, the Department of Chemistry and Industrial Chemistry, has been the local coordinator of PLS-Chemistry for the Liguria region since 2005. The activities that are carried out within the project are designed so as to provide a form of continuous training; in fact, teachers are actively involved in:

- meeting for the production of admission tests for the degree course in chemistry;
- seminars on current topics of chemistry or teaching methodologies;
- meeting to design practical activities to be carried out in the laboratory;
- implementation of laboratory activities with students

The part devoted to the laboratory is usually the most popular, as for the enthusiasm of the students, as because teachers feel not prepared in this area and require help. The collaboration between teachers and university researchers enabled to organize many laboratory activities, carried out both at the Department and at school.

4. The impact of the project on successful experiences

The work of this last year has been particularly challenging for everyone involved because it has allowed us to work in concrete way on tools to teach chemistry and to experiment with students, who are the end beneficiaries.

As every year, the workshop enabled many teachers to meet and share experiences and concerns, and to get valuable tips from the experts.

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The most important innovation of this year was not planned initially as a project activity. It was designed and introduced in order to reinforce the objectives and the project impact on school environment and to enrich the portal with attractive and useful material for teachers.

Following the promoter proposal, during the partners' meeting held in Limerick (27-28 November 2013) all partners agreed that it is necessary to test ICT teaching resources in classroom and in structured way. So, the teachers involved chose and used some portal resources with their students, then producing reports. These reports, uploaded on the new portal section called "testing", contain testimonials and suggestions for educational paths that can be followed and supported by the above tools, tips and considerations from teachers. In particular, the report structure is the following:

- teacher name, affiliation, role in the project
- topics related to the resource
- examples of learning objectives
- practical information regarding the use of the site/simulation.
- information about the class that was involved in the testing
- suggestion for use (how the resource was used and possible alternatives about how the resource can be used)
- considerations about the resource (insights into student use / thinking, teacher's conclusions)
- supporting info (es. worksheets produced by the teacher, if available)
- As highlighted in the next paragraphs, the testing of ICTs in classroom, one ICT resource in particular, was transferred to the national project *Scientific Degrees Plan* as activity carried out in different secondary schools by university researchers, in collaboration with teachers.

4.1 Workshop

The workshop on "Successful experiences" took place in March, the 26th, at the Department of Chemistry and Industrial Chemistry of Genoa

It gathered experts, teachers (also from associated schools) and university staff involved in the project "Chemistry Is All Around Network".

The agenda of the workshop was the following:

- *Presentation of national activities born to support CIAA_NET objectives*
- *Focus on teachers' and experts' personal successful experiences*
- *Discussion on teaching resources tested at national level*
- *Planning of future work*

The project highlighted the different requirements in terms of chemical teaching in schools. For example, from discussions held during the last year workshop, it was found that:

"it is important to have the opportunity to experiment different approaches and methods under the guidance of experts in order to avoid numerous mistakes due to the lack of experience"

"the discussion on ICT resources has highlighted the difficulties that currently schools have in using them .... the lack of teacher training in using digital tools and applications"

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"teachers feel obliged to use them but they do not know how to make them effective for learning"

Accordingly, teacher suggestions were transferred to some activities of the national project *Scientific Degrees Plan (PLS)-Chemistry Area* in order to give a concrete answer to the needs expressed in the framework of the European project (EP).

The workshop started presenting two of them.

1. *Presentation of national activities born to support CIAA_NET objectives*

   The first PLS activity is a course held by Prof. Alberto Regis, who has the role of expert in the CIAA_NET project and the role of training Chemistry teachers in his life. The training course was about the chemical bond and was characterized by the design of worksheets by the collaboration of the teachers involved and Prof. Regis. Alberto Regis, presenting the course, underlined that teachers need to learn how to build by themselves the tools they will use.

   The second PLS task is about using ICTs in teaching Chemistry: for this task, *tavolaperiodica.it* was chosen; the site was introduced to secondary school students of different Institutes during a two-hour lesson in a computer classroom.

   The initiative, that is described more in detail in the next paragraph, showed a positive effect on teachers and students.

2. *Focus on teachers' and experts' personal successful experiences*

   Roberto Antiga, a teacher of an associated lower secondary school, presented a significant experiment created with his class on the topic of thermal conductivity. Students designed and built a lab activity to study the thermal conductivity of four materials: iron, aluminum, copper and wood.

   Following the report by Roberto Antiga, the participants discussed the importance of a teaching laboratory where students can also be designers, and the benefits of joining this experimental activity to a simulation with the purpose of deepening.

   The simulation should give the possibility to repeat virtually the experiment but choosing among several less common materials in order to obtain a meaningful comparison to discuss the properties of metals and non-metals. Then, the possibility of finding such a simulation was discussed.

3. *Discussion on teaching resources tested at national level*

   During the afternoon session of the workshop, the participants were divided into 2 groups. The composition of each group was not accidental but chosen in order to have an expert and at least one exponent for each grade of school.

   The first group, led by Elena Ghibaudi (the expert), discussed the subject "properties of substances" and examined it vertically through the experience of the participants.

   Particularly significant were the experiences presented by Anna Pavan (associated lower secondary school) who pioneered the use of digital resources in supporting experimental activities, lectures or as a tool to organize group works.

   The second group, led by Alberto Regis, discussed the topic "food", in this case also dealt vertically through the experience of participants: from simple macroscopic treatment of key nutrients carried in primary school, the discussion was led to set up principles of biochemistry at the upper secondary school.

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At the conclusion of the discussions, both groups listed the pros and cons of the tools used. They agree that:

- digital tools should be interactive, so as to stimulate the active involvement of the student
- a digital tool cannot be an instrument of self-learning: it cannot replace the teacher and cannot replace the laboratory, but it can be a deepening or a help for students with special educational needs
- it is better to use a digital instrument that deals with few concepts in a clear and focused way
- digital resources can and should be interdisciplinary tools; for example, to learn foreign languages while studying science and vice versa
- attention to the representations of the microscopic level, that digital resources offer: they are powerful tools but they must be adapted to the user's level or they risk to distort completely what you want to convey.

4. *Planning of future work*

On the basis of the above considerations, experts and teachers discussed about the possibility of performing a teaching resource, as future and concluding work of the project. The resource should be organized in three levels of deepening and modeling: 1.suitable for primary school, 2.suitable for lower secondary school and 3. suitable for upper secondary school. It should include simulations with possibility of choosing among more variables and interactive questionnaires. The subject of the resource has been chosen considering the most dealt topics at school, the need of verticality starting from primary school and the personal experience of the participants. Accordingly, the agreed topic was solubility.

4.2 Testing of ICTs

The seven ICT resources tested till now are briefly described in terms of practical information regarding the use of the resource and the considerations made by the teacher.

Balloons and static electricity + Circuits + John Travoltage (from PhET site) [3]

The three simulations were used in order to integrate frontal lessons about electricity: electric charges in materials, static electricity and electricity associated to circuits.

- At first, by using the whiteboard (no computer lab was available), the teacher showed the collection of simulations available on PhET site and how to use them.
- Then, students were asked to explore PhET site, individually at home. Their task was to search and try simulations inherent to electricity and give an assessment about the possibility of using them to better understand the contents learned in class.
- The results of their work were discussed in class: some simulations were rejected because not clear for them or because the animation did not work. Three simulations were considered positively and used in class with the whiteboard:
- balloons and static electricity
- John Travoltage

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- signal circuit
- Some experiments suggested by the simulations were performed also practically: teachers and students together planned the experiences to carry out and the needed materials were brought from home. Easy activities about static electricity were realized with balloons, wool, plastic, glass and other materials in order to confirm and deepen what showed by the simulation. A basic circuit was also built in class.
- As conclusion, students, divided in groups, summarized the performed work and drawn their conclusions writing a brief report.
- A short summary of the reports was produced as PPT presentation with the whiteboard and with the collaboration of the whole class (supporting info).

The resource provided interesting insights to undertake, with the lab approach, a path of observation about the concept of electricity. Moreover, simulations give the possibility of planning more interactive lessons, where the student has an active role and feels to be protagonist with the teacher and schoolmates.

The whiteboard support was very important to make the work easier and more interactive: simulations can be analyzed and used autonomously at home, but a work in class under the guidance of the teacher is fundamental to fix the concepts and avoid misconceptions.

Biochemistry Unit [21]

Before starting the work with the resource, the teacher briefly introduced pupils to nutrients.

The resources used are those of section red, orange and yellow and the modality of use can be summarized as follows:

- Autonomous exploration of the resource, by the student, supported by a questionnaire survey on the interest and interactivity of the same
- Use of simulations accompanied by structured sheets provided by the teacher
- Work of review and summary of the activities with task to be carried out in small groups at school or at home
- Implementation of laboratory activities to reply virtual simulations proposed in the resource (i.e to check the solubility of glucose and starch in water)
- Translation from English to Italian of sections of the resource with particular attention to the specific scientific language.

The distrust in the use of the resource in a foreign language was overcome by the easiness in translating the scientific terms. In addition, the use of the resource in small groups provided a valuable opportunity for cooperative learning activities.

The results obtained in the final evaluation of the learning supported by the resource Biochemistry were definitely positive.

Before using interactive sections, a preliminary survey on students' spontaneous conceptions could be done.

Chemistry at home [22]

The resource was used in the following way:

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1. Pupils in the class, divided into groups, explored part of the resource (chemical substances in food) focusing on the reaction between vinegar and baking soda. The purpose of the exploration was to collect information on factors that could affect the reaction itself.
2. Each group chose a particular experimental factor to test and organized the experimental activity (how to do it, which materials to take from home..)
3. Each group carried out the experimental activity in the classroom, showing it to the other groups.
4. Each group produced the scientific report of all the activities (carried out and observed).

The work was carried out with the help of the Comenius Assistant because available in the school. A good alternative is to organize at least part of the activities with the English teacher.

The reaction of students in approaching the resource in English has been positive: it is an effective tool to widen and consolidate students linguistic competence without conflicting with formal English teaching; they showed cooperative attitudes and did not find difficulties in understanding the contents and using the information to organize the practical activities

The resource provided interesting insights to undertake, with the laboratory approach, a path of observation and reflection on a common chemical reaction such as that between vinegar and baking soda.

The availability of the resource in English also represented an opportunity to experience the CLIL (Content and language integrated learning) in building scientific skills.

The support of the whiteboard favored the cooperative learning approach, through continuous moments of sharing between the groups of pupils.

Density (from PhET site) [3]

The resource was used as follows:

- At first the general concept of density was presented as property of objects related to mass and volume. As a first evidence, objects with similar volume but different weight were examined, as well as objects with similar weight but different volume.
- Then using the whiteboard (no computer lab was available), the teacher showed the resource to pupils in order to connect density to the phenomenon of floating and sinking of different materials.
- Thereafter, the resource was used by experiencing the proposed different variables: students, in turns, decided what to change and discussed the results with the rest of the class.
- The teacher asked students to plan a simple experiment with the purpose of reproducing at least partially what outlined in the on-line resource.
- The experiment planned was carried out after bringing from home simple materials. Students calculated density using a balance and the displacement of water when dropping an object. They also tried to identify unknown materials by calculating their density.
- Finally students, divided in groups, summarized the performed work and drew their conclusions writing a brief report.
- A short summary of the reports was produced as PPT presentation with the whiteboard and with the collaboration of the whole class.

The resource provided interesting insights to undertake, with the lab approach, a path of observation and reflection on a material feature (density). In particular, it helps to develop the following skills:

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- Measure the volume of an object by observing the amount of fluid it displaces.
- Provide evidence and reasoning on how objects of similar mass can have different volume and on how objects of similar volume can have different mass.
- Identify the unknown materials by tables provided in the simulation.

Food Education [23]

Teacher can organize a scientific 'treasure hunt' in the following way:

- to divide the class into groups of two or three pupils
- to propose open questions about nutrients, to be answered by consulting the site
- to propose a final question connected with the previous open questions
- Who finishes the job can play games about the nutrients present on the site
- At the end groups share their answers and their comments

Worksheets to fill in during the treasure hunt can be produced by the teacher with the treasure hunt generator site (http://www.aula21.net/cazas/cacce.htm), as reported in the example uploaded in the supporting info section.

Pupils performed the task with pleasure, as if it were a game, but also very seriously, trying to get the highest score looking for all the elements necessary to answer the final question.

Navigating the site was easy also for very young pupils, but sometimes the teacher had to mediate some of the concepts unknown to so young students, as "cells", "plastic function", "enzymes" and so on, however they focused the main nutrients and principles of food education. They showed good cooperative attitudes.

The resource provided interesting insights to undertake a path of reflection on the food pyramid and a proper diet with local seasonal foods.

Virtual experiment: viscosity explorer 2012 [24]

At first it is necessary that students knows the meaning of substance and the state transitions of the matter.

A sequence of actions to use the simulation is the following:

1. free and individual exploration;
2. analysis of the simulation after that the teacher focused the attention of pupils on aspects to be deepened; in this case the use of the whiteboard is suggested;
3. organization of the class in small groups in order to use the simulation in a functional way (see objectives;
4. discussion about the opinions of each group while the teacher is summarizing at the whiteboard;
5. use of the discussion summary with the aim of producing individual maps that link the new concepts with the old ones
6. production of a shared conceptual map from the analysis of the individual maps (even with the whiteboard)
7. individual deepening on the single points of the above map in order to prepare the pupils to the study of new topics.

The use of the resource is very intuitive, the English language is not an obstacle for children who had no problems at the time of free exploration. Teacher's intervention was necessary to bring pupils to overcome

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the playful aspect and make them concentrate on a functional use of simulation in the construction of new knowledge, connected to prior learning.

Work in small groups (pairs or at most three children per computer) helps to control the use of simulation in order to discover the characteristics of the substances, the effects of heat on them or similar thus coming to few conclusions and links with the knowledge built into earlier stages of the course.

The simulation puts children in front of the implementation of what was suggested, analyzed and studied earlier during the course, as to make it easier to understand and to provide references for a stable storage.

Tavolaperiodica.it [25]

The resource was used as tool of deepening of metals, topic presented by the teacher with frontal lessons.

- At first, the class explored the resource by using the whiteboard in order to understand the structure of the site and its contents.
- As homework, some students were asked to search information about the periodic table of elements, the others about metals.
- In the classroom, collected information were discussed and shared
- Then the resource was explored focusing the attention on metals and on extraction of metals from ores: under the guidance of the teacher, they discussed videos and related explanatory texts.
- Using objects of common use brought from home (copper wires, aluminum sheets and tins, nails etc.), direct observation of some metals and analyses of their characteristics was done.
- A simple experiment was suggested by the teacher in order to show that metals can react with other substances: reaction of the aluminum put in protracted contact with an even weak acid, such as lemon juice. Students decided what to bring from home and performed the experiment at school.
- As conclusion, students, divided in groups, summarized the performed work and drawn their conclusions writing a brief report.
- A short summary of the reports was produced as PPT presentation with the whiteboard and with the collaboration of the whole class
- The resource is useful because:
- it is rich of videos that can be commented by teacher and students. Videos are not only of chemical reactions but also about properties of some simple substances.
- Text are simple and students do not find difficulties in understanding them
- The site is simple but rich of contents and each one can find links with curricular topics
- The site is suitable for upper secondary school students, but it can be used fruitfully also at lower secondary school. In this case the guidance of the teacher is fundamental in order to select and use only sections that can be understood by so young students.

Moreover, as mentioned in the paragraph 5.1, the testing of Tavolaperiodica.it was included in the national project PLS and carried out by Laura Ricco. The objective was not only to encourage teachers to introduce ICT resources, but to help introducing them in a meaningful way, so that they are not disconnected but used in synergy with other educational approaches, from the traditional lesson to the lab. The site Tavolaperiodica.it was chosen because it is a very simple but effective resource that provides in-depth prompts and concerns a traditional subject of the secondary school curriculum: the periodic table of the

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elements. It was introduced to secondary school students during a two-hour lesson that took place entirely in a computer classroom.

The activity combined the resource with different teaching approaches: discussion in small groups, the deduction based on video observation, references to history, contact with samples of real substances in ordinary or less ordinary use, small experimental demonstrations, etc.

This activity did not presume to set up a "model lesson" on the periodic table, but simply wanted to demonstrate how a digital resource can be "naturally" integrated with the traditional teaching, providing in-depth insights, or clarifying the contents, or showing a way to convey the attention where the traditional lesson struggles.

The initiative showed a positive effect on teachers and students: Laura Ricco met 10 enthusiast classes (9 classes of upper secondary school and 1 class of lower secondary school) that answered positively to a question about the motivating role of the experience. Finally, a focus group with teachers involved in the activity and with colleagues working at the Department of Education was carried out in order to discuss about results, impressions and adoption of the resource as tool to teach elements and the periodic table.

5. Conclusions

The last year of the project has been assessed by the national team as the most interesting and engaging.

The theme of the successful experiences involved teachers in research and evaluation of tools to use with students. They could present their experiences and compare them with those of colleagues, thanks to the national workshop held in March; here, the discussion with experts revealed strengths and weaknesses in the teaching of each one, gave new ideas for improvement and strengthened collaborations.

The testing of some ICT resources, chosen among those uploaded on the portal database, gave further substance to the project, reinforcing the objectives and the impact on schools.

We believe that the rich database of successful experiences and of ICT resources, that were the subject of intense work by qualified teams from different countries, is very significant nowadays, not only for Italian teachers, but for all those who deal of science education in Europe.

In 2000, the European Union started a process well known as the "Lisbon Strategy": 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. 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.

Italy conformed with a reform of the school system that finds its latest version in the New National Guidelines of 2012. Text outlines the duty of a new education, based on the development of competences: all schools will have to adapt, starting from primary school, designing curricula to comply. All this led to the urgent need to change the teaching methodology, to resort to new and more appropriate educational tools and to design, collaborating vertically.

In this new panorama of Italian educational system (but also European), primary school is not only the starting point of education, but its pillar: the educational objectives and the student's profile at the end of the

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five years are crucial to a proper development of competences in the following grade levels and to properly set up the basics of the different disciplines. 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 choice of successful experiences and the testing of digital resources tried to be as consistent as possible with what above discussed, involving teachers and students of all school grades and stimulating the collaboration between them.

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