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Successful Experiences in Chemistry Teaching in Portugal

Lifelong Learning Programme

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SUCCESSFUL EXPERIENCES IN CHEMISTRY TEACHING IN PORTUGAL

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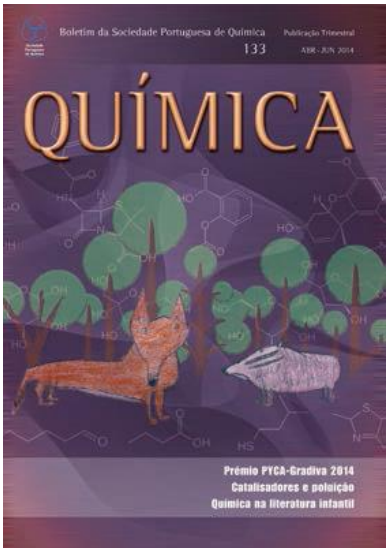
ABSTRACT

This report presents the results of the work performed within the third year of the Chemistry is All Around Network Project on the thematic "Successful experiences in chemistry teaching". Apart from the bibliographic indications, the presented results are based on the experience shown by the participant teachers. An overview of the available national resources to support teaching activities was done and three selected examples of successful experiences were described (Casa das Ciências (House of Sciences), Química das Coisas (Chemistry of Things) and Portuguese network of Science Museums). A special focus was given to the testing of digital resources where an innovative method using the mediation of learning guides was used. This activity was organized in cooperation with the CFAE-Bragança (Centro de Formação de Associações de Escolas - Training centers associated with school associations). Fourteen teachers were involved in the testing of digital resources that reached a population of 120 students. Particularizing for the digital resource "Radioactivity: beta decay, alpha decay and radioactive dating" included in the Phet portal (Phet: http://www.ptable.com/), 30 students with an average age of 17 years old were involved. The competences and the learning results acquired by students, evaluated through the application of pre- and post-tests, pointed out for a normalized gain of 0.64. In conclusion, the activities carried out during the third year dealing with the testing of digital resources, was evaluated very positively by the participating teachers and found profit for their careers.

1. Introduction

In the Portuguese context some examples of science/chemistry sources to support teaching work can be cited, some of them related with school manuals editors. An example of this last case is the teacher area entitled "Espaço Professor Porto Editora" provided by Porto Editora. Apart from the mentioned cases, and according to the Portuguese Chemistry is All Around network of teachers, the most relevant and used are:



(i) Casa das Ciências (House of sciences) **(http://www.casadasciencias.org/)**: this portal is a website for Science teachers, supporting teaching activities in different areas of science, and several educational levels (primary and secondary education, but also higher education). Moreover, the project is presently editing a journal "Revista de Ciência Elementar".

(ii) A Química das Coisas (Chemistry of things) **(http://www.casadasciencias.org/)**: this project originally developed to disseminate science became very popular among teachers being their resources used mainly as motivating elements. According to teachers, the success relies on the fact of being scientifically rigorous and appellative, but short enough to not compromise the time needed to work with students.

(iii) Boletim da Sociedade Portuguesa de Química: this is a journal edited by the Portuguese Society of Chemistry that can be found online in its webpage **(http://www.spq.pt)**. It includes an educational section entitled "Chemistry and teaching" and a section devoted to children "Chemistry for children". Here teachers can found several experimental activities to implement at laboratorial classes.

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(iv) Educative resource section from the Portuguese Ministry of Education and Science (**http://www.dgidc.min-edu.pt**): as a complement to the educational programs, teachers can find in this website guides and materials to support their teaching activity.

2. Key competences and their development in chemistry education

The school system in Portugal is organized in three sequential levels: pre-primary education (ages 3 to 5), basic education (typical ages 6 to 15) and secondary education (typical ages 15 to 18). Basic education is organized according to three cycles (1st cycle (grades 1-4), 2nd (grades 5-6) and 3th (grades 7-9)).

Apart from the pre-primary education, where some science activities/projects are introduced, chemistry related subjects start to be taught during the basic education (1st and 2nd cycles) as part of Environment Study. Chemistry dedicated courses started with Physical-Chemistry Sciences in the 3th cycle, Physics and Chemistry A (10-11th grades) and Chemistry (12th grade, elective) in the secondary level. Chemistry teaching presently follows a context-based approach.

According to the Portuguese Ministry of Education and Science (Direção Geral da Educação – Programas e Metas Curriculares do Ensino Básico, 2014: http://www.dgidc.min-edu.pt/) the following key competences are defined:

1st and 2nd cycle:

The objective of these two cycles is to awaken curiosity by natural phenomena and identify the physical and chemical characteristics of the surrounding world. The scientific initiation begins with the curricular unit of "Environmental Study" integrating Physical and Natural Sciences, among others. The general character of this course promotes the development of the following skills:

(i) Explain phenomena based on materials properties;
(ii) Treat information, analyze data, formulate hypothesizes and find solutions;
(iii) Explain phenomena based on physical and chemical properties;
(iv) Recognize the importance of experimentation in the interpretation of scientific phenomena;
(v) Participate on experimental activities of discovering and research;
(vi) Arouse curiosity and create a feeling of respect, enthusiasm and interest in science.

3th cycle (7-9th grades):

The objectives of Physical-Chemistry Sciences are:

(i) Stimulate the enthusiasm and interest in science so that young people feel confident and competent to engage scientific and technical themes;
(ii) Recognize the wide range of materials with different properties and uses, as well as the role of chemistry in their identification and transformation;
(iii) Characterize, qualitatively and quantitatively, solutions. Prepare at laboratorial level aqueous solutions of a given weight concentration;
(iv) Recognize physical and chemical transformations and conclude that they can involve absorption or energy release;
(v) Recognize the particle nature of matter and the diversity of materials through their structural units;
(vi) Understand the meaning of the chemical symbology and the concept of mass conservation in chemical reactions;
(vii) Understand the periodic table organization and its relationship with the atomic structure. Use elements information to explain physical and chemical properties of the respective elemental substances.

Secondary school (10º, 11º and 12º grades):

In accordance with the Reform of Secondary Education principles, the curricular unit of Chemistry (12º grade) and the one of Physics and Chemistry A (11th and 11th years) are guided by common principles. It is intended, in this stage of secondary education, that students maintain the interest to proceed science and technological carrers. Skills based on contemporary authors and in organizations such as the OECD that

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consider fundamental scientific literacy promotion. There are three dimensions of competences to consider: knowledge, actions and values, which in the case of chemistry may be the following:

Knowledge dimension:

(i) Content skills (declarative and conceptual knowledge in the field of chemistry);
(ii) Epistemological skills (overview of science meaning, and chemistry in particular, as a way of seeing the world, distinct from other interpretations).

Actions dimension:

(i) Learning skills (ability to use different learning strategies and construction modes of scientific knowledge);
(ii) Social skills (ability to cooperate with others in order to collect data, follow protocols or interpret scientific information);
(iii) Procedural skills (ability to observe and experiment, evaluate, interpret graphs, use models, critically analyse situations, generate and test hypotheses);
(iv) Communication skills (ability to use and understand scientific language, register, read and argue using scientific information).

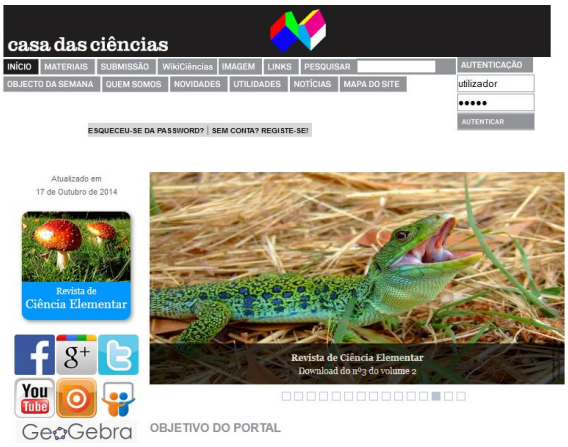
Values dimension:

(i) It refers the ethical competences (standards knowledge, their relativeness in local contexts and their temporal character).

3. Examples of successful experiences

Here 3 selected examples of successful experiences, chosen based on the opinion of the Chemistry is All Around network participant teachers.

3.1. Casa das Ciências (http://www.casadasciencias.org/)



Casa das Ciências (House of Sciences), a project sponsored by Fundação Calouste Gulbenkian (Calouste Gulbenkian Foundation), is a website for Science teachers that promote the use of information technologies (ICT) in the educational process. The main objectives and results of this project will be described based on the work presented at the International Conference on Successful Experiences and Good Practices in Chemistry Education (SEGPCE), held in May 21 in Bragança, within the context of the project Chemistry is all Around Network [1].

Casa das Ciências supports teaching activities in different areas of science and several educational levels (primary and secondary education, but also higher education). The site is gradually becoming a portal "from teachers to teachers" being a space where they can find useful and effective materials for their professional activity. It is a place where they can exchange ideas about the materials and the way they can be used. In conclusion it is a space for sharing experiences.

All the materials available on the portal or recommended by it are firstly evaluated from a scientific and educational point of view, according to a peer review methodology. Currently, the acceptance by the Editorial Board and subsequent publication is recognized as prestigious, in analogy with the usual scientific publications. The portal has over 12,600 registered members with a Portuguese science teacher's penetration rate exceeding 30%. With over 4 million cumulative views in all of its components, the global daily demand is up to 3-4 thousand visitors, with a significant impact (some components above 40 %) from other Portuguese speaking countries.

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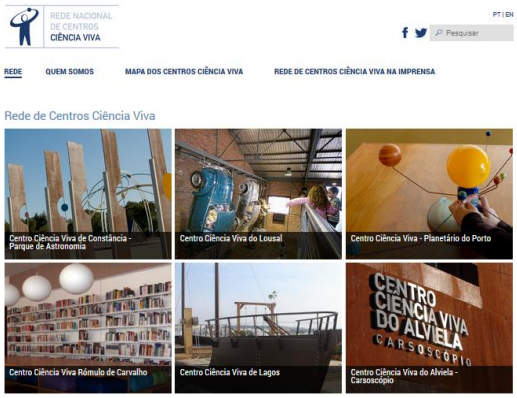
The portal also includes a wiki section, the Wikiciências (http://wikiciencias.casadasciencias.org) and an image bank (http://imagem.casadasciencias.org/). Moreover, the project is presently editing “Revista de Ciência Elementar”.

3.2. A Química das Coisas (http://www.casadasciencias.org/)

"The Chemistry of Things" is a media project dedicated to present the chemistry hidden in our lives, showing often how scientific developments can result in the improvement of the welfare of modern society. Each TV episode, available for download at the website, is devoted to a theme. The first series titles are the chemistry of Tattoos, Salt, Breakfast Cereals, Alcohol, Post-its, Nail Polish, Laptops, Contact Lenses, Decaf, Detergents, Sleep and Love. This digital resource is very well written, scientifically rigorous, with a beautiful design and attractive animations. It is not interactive. As each episode lasts 2-3 minutes, it can be used as a thematic introduction and a factor of motivation in classroom. Additionally, the authors also make available smaller videos, usually animations, that can be used independently by the teacher. For example, related to the episode “The chemistry of breakfast cereals”, two smaller videos can also be downloaded: one about the Periodic Table of Elements, highlighting iron and, another, about the metallic iron oxidation in the stomach originating iron ions - a form usable by the body.

Although the use of this resource as an educational tool was not foreseen in its creation it is presently used by teachers mainly as an introductory motivation element. Its success relies on the fact of being scientifically rigorous and appellative, but short enough not to compromise the time needed to work with students.

The site has Portuguese and English versions. But the videos have the option of introducing subtitles in several languages: Bulgarian, English, French, Greek, Italian, Polish, Portuguese, Slovak, Spanish, Turkish, etc.



3.3. Portuguese network of Science Museums (http://www.cienciaviva.pt/centroscv/rede/)

The Portuguese Network of Science Museums is coordinated by “Ciência Viva - Agência Nacional para a Cultura Científica e Tecnológica”, agency created in 1996 to promote scientific and technological culture in Portugal, with special focus on youths. The network is constituted by 20 science centres covering the entire national territory. These centres are interactive spaces of scientific and technological dissemination and act as regional development platforms (scientific, economic and cultural) through the promotion of the more active regional actors in these areas. This is the case of the “Centro Ciência Viva” in Bragança that since its foundation has a strong cooperation with the Polytechnic Institute of Bragança (IPB). Among the developed initiatives it is woth to mention the science dissemination project Ciência@Bragança (http://www.cienciabraganca.pt/).

The science museums play an important role in the creation and diffusion of scientific and technological culture. Moreover they can be explored by teachers, not only in formal visits, but also to complement classes taking advantage of the installed scientific capacity [2].

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4. The Impact of the Project on Successful Experiences

4.1 Workshop

The workshop on “Successful experiences and good practices in chemical education” promoted by the Polytechnic Institute of Bragança (IPB) was held in the School of Technology and Management (ESTiG) of IPB at 02 of April 2014 (16:00 CET), in Bragança.

Nineteen persons, among teachers from various school levels (15) and IPB staff (4) were present. In this third year dedicated to the thematic “Successful experiences and good practices in chemistry education” the workshop comprised a practical session devoted to the exploitation of a digital resource and the elaboration of a learning guide envisaging its future use with students.

The workshop started with a brief presentation of the “Chemistry is all around network project” in what concerns main activities carried out and results achieved during the third year. The need to proceed with the analysis of the international papers and publications uploaded in the portal was remembered to the participants. An example of a review was presented.

Taking advantage of the experience of Professora Adília Tavares da Silva (Escola Secundária Abade Baçal) in the application of digital resources to support chemistry teaching, she gave a presentation on the thematic “Learning guides as a tool to mediate student’s learning process”. The following objectives were drawn:

(i) Fundamentals and advantages of using digital resources supported by learning guides;
(ii) Fundamentals for an effective learning guide elaboration;
(iii) Analysis of digital resources and testing of a learning guide.

Participants were organized in groups of two, sharing a common computer. An example of a learning guide was provided. The thematic chosen was “Radioactivity: beta decay, alpha decay and radioactive dating” aiming at illustrate an example where laboratorial practice is not possible and the understanding of microscopic level applies. The tested digital resources where extracted from the portal Phet (http://www.ptable.com/).

Testing the teaching resource

Portal Phet (http://www.ptable.com/)

The digital resource was explored and tested by the teachers, following the instructions described in the learning guide and by answering the proposed challenges. The envisaged methodology (testing of digital resources using learning guides) was found effective by the participating teachers. They agree that the use of computer simulations in chemistry classes is useful and effective when explored within the framework of a learning guide.

Following this activity, the participating teachers have been provided with the fundamental tools to support the development of further learning guides based on the digital resources available at the “Chemistry is all around network” portal.

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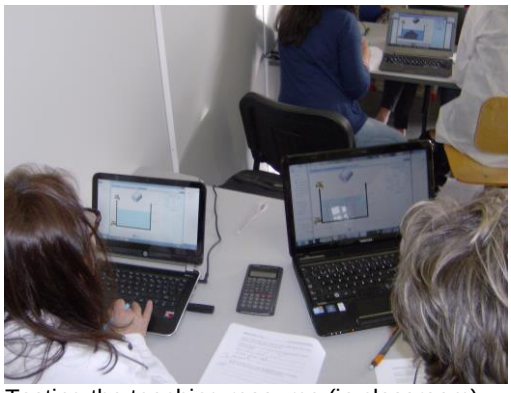
In conclusion, the workshop and activities carried out during the third year of the project were evaluated very positively by the participating teachers. In order to guarantee the success and continuation of the actions carried out were included in a training action with the support of CFAE-Bragança (Centro de Formação de Associações de Escolas - Training centers associated with school associations).

4.2 Testing of ICTs

In this point the test of digital resources performed by the Portuguese Chemistry is All Around team will be described. Following the work started during the workshop, teachers have selected a digital resource and developed a learning guide to be tested in classroom with their students. The classroom sessions were complemented with experimental work. Fourteen teachers were involved in the testing of digital resources that reached a population of 120 students. The following resources have been tested:

(i) Acid-base titration, Chemistry Companion Site, 11/e, Raymond Chang, William College, Kenneth Goldsby, Florida State University.
(ii) Electrochemical Series, Chemistry Experiment Simulations and Conceptual Computer
(iii) Periodic table of elements
(iv) Phet (Alpha decay, Beta decay)
(v) Phet (Circuit Construction Kit, DC Only)
(vi) Phet (Energy Skate Park)


Testing the teaching resource (in classroom)


Validating the teaching resource (in the lab)

The testing of digital resources will be demonstrated here with the example “Radioactivity: beta decay, alpha decay and radioactive dating” (Phet: http://www.ptable.com/):

(i) Alfa decay: http://phet.colorado.edu/pt/simulation/alpha-decay
(ii) Beta decay: http://phet.colorado.edu/pt/simulation/beta-decay
(iii) Radioactive dating game: http://phet.colorado.edu/pt/simulation/radioactive-dating-game

A methodology supported by the use of a learning guide was used. Learning guides are mediation tools created to support software exploitation and guide students during their learning process by helping them to organize and structure knowledge in a global and transversal way. In that way, students will use computers and educational software to interact with scientific models by changing data and variables, engaging in the exploration of the physical situation, persisting in performing the task, showing initiative, taking control of their actions by making proposals, formulating new questions and managing to involve other students in task accomplishment and exploring the situation.

A learning guide is structured in the following parts:

(i) **Challenge-Tasks:** Guidelines are given and questions are formulated in the form of a challenge, to understand concepts, laws, and principles, guiding students in the exploration of physical situations. Conditions for hypotheses formulation are created from the analysed images and the interaction with the software is promoted to allow testing the formulated hypotheses.

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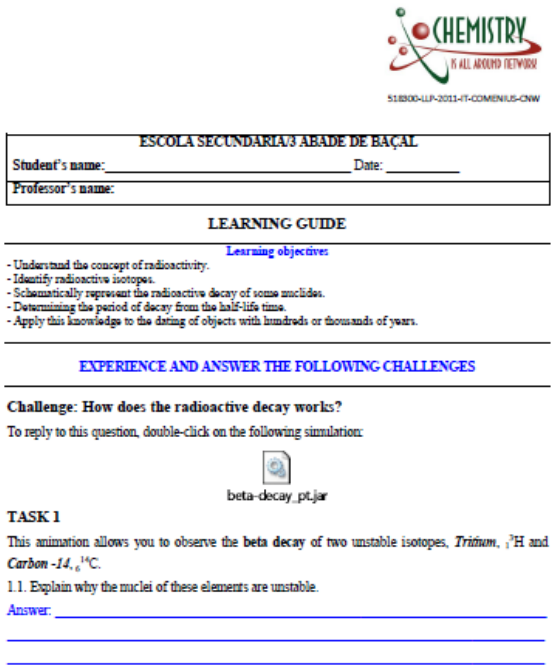
(ii) **To test:** Laboratory intervention activities are proposed combined with the exploration of interactive simulations, to be performed collaboratively. The objective is to stimulate students' autonomy and initiative. Tasks that establish the link between the macro and micro environment of chemical transformations are proposed.

(iii) **To know more:** The main objective of this final part of the learning guide is to awaken students to a comprehensive and interdisciplinary approach, valuing both skills and knowledge through its application to everyday life situations, therefore, attributing meaning and usefulness to scientific knowledge.



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ESCOLA SECUNDÁRIA/3 ABADE DE BAÇAL

Student's name:_____ Date: _____

Professor's name:

LEARNING GUIDE

Learning objectives

- Understand the concept of radioactivity.
- Identify radioactive isotopes.
- Schematically represent the radioactive decay of some nuclides.
- Determining the period of decay from the half-life time.
- Apply this knowledge to the dating of objects with hundreds or thousands of years.

EXPERIENCE AND ANSWER THE FOLLOWING CHALLENGES

Challenge: How does the radioactive decay works?

To reply to this question, double-click on the following simulation:

beta-decay_pt.jar

TASK 1

This animation allows you to observe the **beta decay** of two unstable isotopes, ***Tritium***, $_1^3H$ and ***Carbon -14***, $_6^{14}C$.

1.1. Explain why the nuclei of these elements are unstable.

Answer: _____

The prepared learning guide for the activity "Radioactivity: beta decay, alpha decay and radioactive dating" is partially shown in the figure below.

The activity was performed by a chemistry teacher using two classes of 90 minutes each, and having 30 students with an average age of 17 years old, at the Abade de Baçal High school located in the city of Bragança, Portugal. The competences and the learning results acquired by students were evaluated through the application of pre- and post-tests, i.e., tests applied before and after the classes. The evaluation of the performed tests pointed out for a normalized gain of 0.64.

The students' opinion about the used digital resource was collected by means of questionnaires. A vast majority of students (>90%) found the digital resources used interesting and more efficient than books, considering that they promoted the interaction with a fellow student, centering the discussion on chemistry themes. 70.8% thought that the resources used facilitated their understanding of the studied concepts. Evidence gathered suggests that the use of digital resources mediated by the teacher and by learning guides can enhance significant learning.

5. Conclusions

This report presents the results of the work performed within the third year of the Chemistry is All Around Network Project on the thematic "Successful experiences in chemistry teaching". Among the valuable results achieved, the testing of digital resources following a Learning Guide must be highlighted. Two main conclusions from that experience can be drawn: (i) Digital resources constitute powerful tools available for scientific exploitation that must be mediated by the teacher and Learning Guides to propitiate significant learning; (ii) The combination of interactive digital tools with laboratory work can improve the classroom environment and the quality of student learning.

6. Bibliography and References

[1] Pinto, M.L.S. (2014), Casa das Ciências – A collaborative website for science teachers, Proceedings of the International Conference on Successful Experiences and Good Practices in Chemistry Education (Bragança, Portugal), 7-8.

[2] Silva, J.P. Cravino, J. Anacleto, J. B. Lopes (2012). A Mediação em Sala de Aula no Ensino das Ciências Físicas com Utilização de Recursos Computacionais. Book of Abstracts, Física 2012, 18ª Conferência nacional de Física and 22º Encontro Ibérico para o Ensino da Física. University of Aveiro, p. 215, available in http://www.gazetadefisica.publ.pt/actas/21/pdf

[3] Casa das Ciências (http://www.casadasciencias.org/).

[4] Química das Coisas (http://www.casadasciencias.org/).

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[5] Boletim da Sociedade Portuguesa de Química (http://www.spq.pt)
[6] Rede de Centros de Ciência Viva (http://www.cienciaviva.pt/centroscv/rede/)
[7] Portal Phet:
Alfa decay: http://phet.colorado.edu/pt/simulation/alpha-decay;
Beta decay: http://phet.colorado.edu/pt/simulation/beta-decay;
[8] Radioactive dating game: http://phet.colorado.edu/pt/simulation/radioactive-dating-game
[9] Ministério da Educação e Ciência, Direção Geral de Educação – Programas e Metas Curriculares do Ensino Básico, 2014 (http://www.dgidc.min-edu.pt/).

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