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Virtual tools: virtual laboratories for experimental science – an experience with VCL tool

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Abstract

A fundamental aspect within the configuration of the new European Higher Education Area (EHEA) is that students play an active role in their own learning process. On this educative model of academic formation, the teacher participates as a guide during the teaching-learning process of the student and so he or she must apply constructivist learning models in which new technologies are substantially present. In this regard, the use of tools such as virtual laboratories (which can be found as interactive resources on the web or in digital format from several publishers) can be very effective, for they allow the student to approach real systems and do research on their behaviour with regard to the modification of certain parameters. An experience on the use of the VCL tool on several Chemistry classes will be presented in this contribution. These resources are very useful for the acquisition of several competencies not only when used as teaching materials, but also when integrated as part of the teaching methodology, on an environment of face-to-face or virtual classes, thus reinforcing the teacher-student cooperative work within a constructivist learning context.

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Keywords: tutoring; virtual tools; virtual laboratory; cooperative work; teaching material; constructivist learning.

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1. Introduction

1.1. Question posed

The EHEA setting poses an important challenge on the academic environment at the university level, since it demands a methodological change on the complex teaching-learning process. This new horizon makes it clear that this process is focused on students and their own role in the learning process, as well as on the acquisition of competences. In this way, students assume a very active role in their training and acquire responsibility towards themselves and their learning process. Only then can one of the biggest challenges of this new teaching-learning paradigm be achieved, which is the students' acceptance that this process must continue through life and it is not to be restricted to their time spent behind the university walls. Within this context, finding tools that can be implemented in the teaching methodology is very useful, so they reinforce that necessary sense of responsibility in the student and provide him or her with the necessary learning autonomy that he or she must develop through life. In this respect, virtual laboratories are very useful, since they can either be used as a tool for support and reinforcement so students make the most of their knowledge, or they can be implemented as a teaching resource in expository class sessions in order to encourage a participatory, constructivist environment. In addition to that, the acquisition of competences in the use of ICT (Information and Communication Technologies), which are of the outmost importance for the students training, is enhanced through the use of virtual laboratories.

1.2. Contextualization of the question posed

In the Prague communiqué (2001), there is a reference to this type of permanent learning pursued by the EHEA, which is based, to a great extent, on the use of ICT: 'Lifelong learning as a key factor in the EHEA, given that, in the future Europe based on a knowledge-driven society and economy, the strategies to learn throughout life will become more necessary in order to confront the challenges of competitiveness and the use of ICT.'

According to J. Salinas (2004): 'The training methodologies relying on ICT lead to new conceptions of the teaching-learning process that enhance the learner's active involvement in the learning process; the attention to the emotional and intellectual skills at different levels; the preparation of young people to take responsibilities in a rapidly and constantly changing world; the students' flexibility to enter a workplace that will demand lifelong learning; and the necessary competencies for this continuous learning process.' These quotes point out the importance of the continuous renovation of knowledge and of the correct use of the technological means available. These new technologies are very diverse and their incorporation into the classroom is subjugated to some criteria, according to Sangrá and González Sanmaned (2004): 'Two core elements are necessary for the integration of ICT to become a functioning reality that provides added value: the first one being a reorganization of the institutions that endows those technologies with the necessary agility to respond to the last demands of the society of information and knowledge, and which allows them to provide the requested support to be able to enhance teachers' work. The second one, the development of teacher training programs which fill the current gaps in the field and ensure that teachers are trained to properly use ICT resources in their classrooms.'

Overall, the advantages of integrating ICT in university teaching are, among others, the following (Díaz (2004), Rosado (2005)):

- Increasing methodological diversity.
- Increasing accessibility and flexibility.
- Promoting the student's leading role.
- Improving the presentation and comprehensiveness of certain types of information.
- Encouraging cooperative work.
- Improving individual work.
- Gaining access to new environments and situations.
- Optimizing resources and costs.

ICT play a key role in the practice of this conception of the learning process focused on the learner, since they can constitute learning experiences related to open problems and tasks that require a critical and reflective thought (Alba Pastor (2005)). These technological tools allow the student to enhance his or her responsibility in the search of materials and documentation beyond class notes, and they provide key support for the student's experimentation of his or her own learning process

ICT, as this paper attempt to demonstrate, offer a wide range of possibilities and are very diverse in nature. In the present work we will focused on one of them, Virtual Laboratories or IT tools that simulate a test laboratory from a virtual learning environment. As we have seen, the cause for Virtual Laboratories basically emerges from the need to create student support systems for their laboratory work with the objective of optimizing the time spent on doing those tasks. Nevertheless, the concept of Virtual Laboratory has been expanded throughout the last two decades (Gámiz Sánchez (2009)):

The doctoral thesis '*Modelo de Referencia de Laboratorios Virtuales y Aplicaciones a Sistemas de Tele-educación*' (Rodrigo (2003)) ('Reference Model of Virtual Laboratories and Applications to Tele-education Systems') gathers most of the historical review related to laboratories. In this regard and to summarise, the following must be noted:

- 1984: the concept of virtual tool appears as an instrument;
- 1992: the term 'virtual laboratory' is coined to refer to a tool used for the development of a simulation laboratory;
- 1994: a study conducted by the Vanderbilt University in USA is presented. In this study, a virtual laboratory is designed, based on simulation, as a support tool to traditional laboratory work, and it concludes with this tool's need to learn the basic abilities and the operation of the equipment, which contributes to optimize students and laboratory personnel's time;
- 1995 – 1996: several works appear. They defined the requirements and necessary components for the success of a virtual laboratory and of any other distance learning system;

- 1997: A review of the rules related to virtual instruments appears in the IMTC conference. This same year, researchers from the Illinois University present a complete electronic instrumentation laboratory available to users through the Internet. This is the first *virtual laboratory with electronic instrument remote control in operation*;

- 1998: A detailed model of a virtual simulation laboratory is described in the IMTC conference and the associated ETIMVIS'98, as well as a teaching laboratory proposal in which students use virtual tools to make their experiments.

- 1999: A detailed explanation on how to set up a virtual laboratory with available commercial elements is described in the IMTC, together with the basic requirements to confront when thinking about designing a virtual laboratory;

- 2000 – present time: Awareness of the importance of virtual laboratories on several teaching fields is increased and diverse virtual laboratories are described in conference articles and magazines, where different methods used in the development of virtual laboratories are described in detail, and possible solutions to improve or implement the performance of virtual laboratories are commented.Methodology

2. Methodology

2.1. Contextualization of the question posed

The study of the implementation of the 'Virtual Chemistry Laboratory' (VCL) tool within the teaching methodology was carried out during the academic years of 2010–2011 and 2011–2012 with reduced groups (< 15 students) in the following subjects:

i) 'Introduction to Materials Science', a third-year subject from the Chemistry Science Degree of the University of Alicante, with 6 theoretical credits and a practical credit (years 2010 – 2011 and 2011 – 2012);
ii) 'Solid-state Chemistry', a six-credit elective subject from the Nanoscience and Molecular Nanotechnology Master'sDegree of the University of Alicante (year 2010 – 2011).

2.2. Materials

The tool 'Virtual General Chemistry Laboratory' (VCL), corresponding to a Prentice Hall's publication, edited by the Pearson Publishing company on its 3rd edition from 2009 with ISBN: 978-607-442-210-8, has been chosen for this work. This tool is highly versatile as far as its scope of application in a classroom is concerned. This publication provides a VCL installation CD and a paper guide for the execution of each practical session proposed.

Fig.1. (left) 'Virtual General Chemistry Laboratory' book cover (ISBN: 978-607-442-210-8); (right) its corresponding CD where the VCL computer program is found for the virtual experiences.

This tool has a package of realistic and complex simulations that encompasses the different experiences that can be carried out in a general chemistry laboratory. In these laboratories, students enter a virtual environment where they are free to make choices and decisions similar to those confronted in an actual laboratory. At the same time, students can experiment the consequences of a good practice or a malpractice in laboratories. Experiments include simulations of qualitative inorganic analyses, fundamental experiments of quantum chemistry, properties of gases, titration experiments, scanning calorimetry, organic synthesis and qualitative organic analysis.

2.3. Instruments

The instrumentation of Virtual Laboratories in the classroom can vary depending on the type of virtual tool we are talking about. Thus, implementing a virtual laboratory tool that is available as a free and toll-free program (free online software) can be relatively easy. However, if it is not a free license program like the one used in this work, the economic factor, so important given the current situation, must be taken into account. The user license for 'Virtual General Chemistry Laboratory' (VCL) is acquired when buying the book. If the methodology to be implemented involves using this tool in the classroom in an expository context, this expense is economically viable since each unit costs a little amount of money making it affordable for any institution. Nevertheless, if the aim is to provide a tool for students to be able to work from home, the purchase of so many programs as students enrolled is not viable. On the other hand, it is more viable to negotiate the purchase of multiple licenses with the publishers (each publisher has its own policy on this regard).

2.4. Procedures

In this study the VCL tool has been exploited in two aspects:

- On the one hand, it has been included as a fundamental element in the explanation of new chemistry concepts in the classroom; to that end the tool has been introduced to the students and it has been used for the execution of several experiences. Afterwards, a debate on the issue has been generated.
- On the other hand, the program has been provided to a small number of students (10 in total), so they could assess from home its utility as reinforcement to the practical sessions of the different subjects and to the concepts seen in class.

In particular, the experiences for which VCL tool has been used are the following:

a) Experiences carried out in the classroom in the context of expository sessions: i) Thomson's cathode ray tube experiment; ii) Rutherford's scattering experiment; and iii) boiling point elevation.
b) Experiences carried out by the students: i) counting of protons, neutrons and electrons; ii) specific heat of aluminium; and iii) freezing point depression.

Students were handed out an anonymous survey in order to collect their opinions with regard to this tool. The results are presented in the following report.

3. Results

The use of this tool both by the teacher in the classroom and the students at home has generated the following results explained in detail. Teacher's opinions derive from: i) his experience with the VCL tool inside the classroom, based on his perceptions with respect to the students' response, both in the required time for the understanding of the concepts explained and the opinions obtained from the debate generated around the question posed; and ii) the perception in the students' use of this tool at home based on the resolved tutoring sessions, doubts in class; etc. On the other hand, the students' criteria with respect to this tool, innovative for them while offered by the teacher for free-use at home, have been collected in the form of an anonymous questionnaire.

- Teacher's opinions

In general, the use of this tool has been very favourable. The advantages of its use in the classroom are multiple since it is a tool that provides a lot of visual information (hence, direct reception), interactive (it holds both the teacher's and the students' attention for the achievement of the different steps required for the accomplishment of a experience) and produces immediate results, exempts from the circumstantial problems which often arise in an actual laboratory (this makes it perfectly possible for the teacher to plan and schedule the activity in terms of time used in the classroom). However, this tool is not exempt from some disadvantages. Advantages and disadvantages of using VCL detected by the teacher are collected in the following charts:

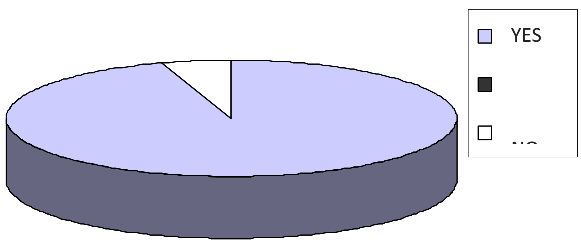
Table 1. Compilation of advantages and disadvantages of using the VCL virtual tool, according to the teacher's opinion, both for its use in the classroom and the use made by the students at home.

Use in the classroom by the teacher	
For the teacher	
Advantages	– possibility of adding laboratory experiences in the classroom – perfect time control of the experiences, since there is no risk of experimental error
Disadvantages	– the activities require extensive planning and a significant investment in time to prepare – it creates a situation of dependence on computer tools
For the students	
Advantages	– better understanding of the topics covered by relating them to experiences – greater ease in relating phenomena and theories
Disadvantages	– lack of interaction with the experience
Use at home by the students	
For the teacher	
Advantages	– it helps to avoid overlapping with the practical sessions of other subjects – it reduces costs and assemblages, being a cheap and efficient alternative to an actual laboratory
Disadvantages	– heavy dependence on computer tools
For the students	
Advantages	– there is no risk involved in experimenting – absolute time flexibility to perform the exercises – it is a self-learning tool
Disadvantages	– misjudgement of the laboratory circumstances

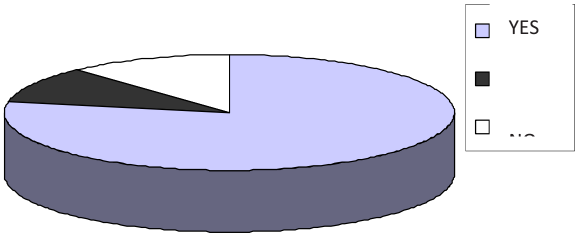
- Students' opinions

Students filled up a simple questionnaire voluntarily and anonymously, in which they were asked questions related to their opinions on the use of the VCL virtual tool. The questions posed and the graphics created according to their answers given are presented below.

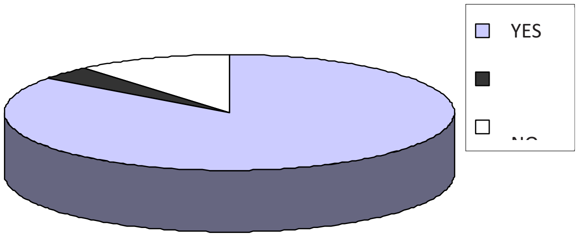
a) Has the use of the VCL virtual tool contributed to understand the concepts explained?



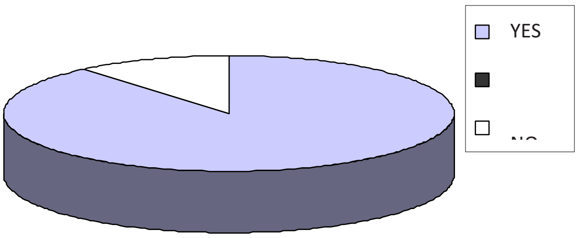
b) Has the use of the VCL virtual tool served to optimize your study and learning time, reducing considerably the time spent on each studied concept?



c) Has the VCL virtual tool helped your self-learning?



d) Do you think that the VCL virtual tool can be useful at an interdisciplinary level for other subjects dealing with the studied concepts?



4. Conclusions

Generally speaking, the use of the VCL virtual tool has produced very positive results, both in its implementation in expository lectures in the classrooms and in the students' use of this tool from home. Nevertheless, while it is true that it is not free of some inconvenient, it provides multiple advantages as it is demonstrated by the results obtained from all the experiences collected by the teacher and from the survey handed out to the students. Any virtual laboratory tool that can be tested positively can be considered an extremely favorable methodological tool in the EHEA context, since it encourages, among other things, students' active participation in a constructivist environment and self-learning. Moreover, it is a perfect complement to the actual laboratory experiences, but never a replacement.

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References

Ferrer, V. (2003). La acción tutorial en la Universidad. En F. Michavila y J. García (coords.), La Tutoría y los nuevos modelos de aprendizaje en la Universidad. Madrid: Consejería de Educación de la Comunidad Autónoma de Madrid/Cátedra UNESCO de Gestión Política Universitaria de la Universidad Politécnica de Madrid, 67-84.

Cano González, R. (2009). Tutoría universitaria y aprendizaje por competencias. ¿Cómo lograrlo? REIFOP, 12 (1), 181-204.

Lyons, N. (1999): El uso del portafolios. Propuestas para un nuevo profesionalismo docente, Buenos Aires, Amorrortu. Frade, L. (2009). La evaluación por competencias. México, 2009.

Martínez-Rojas, J. (2008). [en línea] Las rúbricas en la evaluación escolar: su construcción y su uso. Disponible en: http://www.freewebs.com/cesarmerino/Store%20of%20pub/TPVNM_rev.pdf [2010, 02 de Mayo].

Capote, S. y Sosa, A. (2006). Evaluación. Rubrica y listas de control. Disponible en: http://scholar.google.com.mx/scholar?q=silvia+capote&hl=es&lr= [2010, 12 de Julio].

Appendix

The pictures below are examples of this VCL tool at different levels of an experience.

Fig. 2. Overall look of the Virtual General Chemistry Laboratory, in which different work areas are shown.

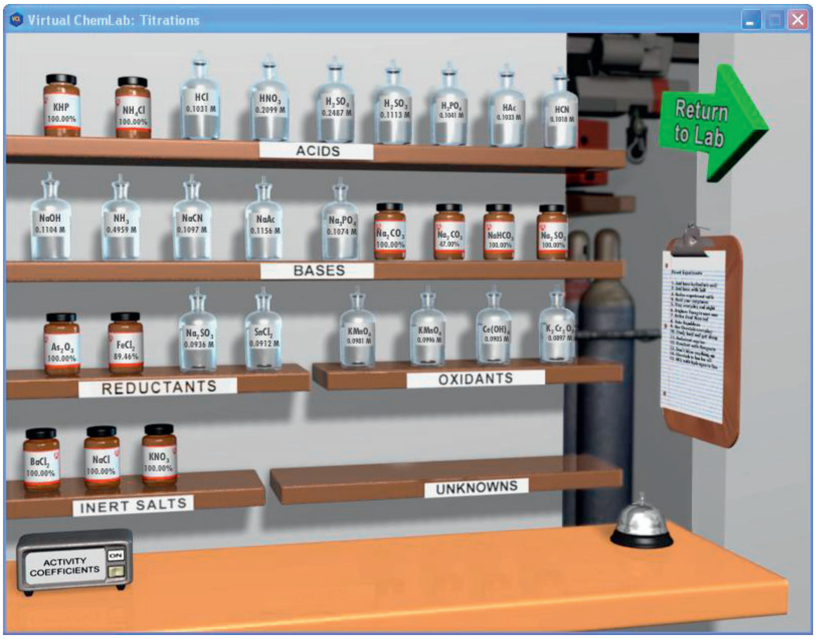

Fig. 3. The Virtual General Chemistry Laboratory provides a realistic environment where all sort of reagents can be found in different storage facilities.

(a) (b)
(c) (d)
(e) (f)

Fig. 4. Images obtained from the Virtual General Chemistry Laboratory: a) electronic book of exercises; b-f) different rooms for the experiments of Atomic Theory, Reactions and Stoichiometry, Thermodynamics, Colligative Properties, Properties of Gases, acid-base Chemistry, and Descriptive Chemistry.