Teaching-learning methodologies: use of blended learning in chemistry laboratory

M.S. Sánchez-Adsuar, J.M. Molina-Jordá

Departamento de Química Inorgánica
Universidad de Alicante

ABSTRACT

For a proper teaching-learning environment in the European Higher Education Area (EHEA) it is mandatory to follow an integral educational program that considers the presential and non-presential activities as a whole, in the understanding of the utmost importance of the out of class students' time. From this point of view, it seems more than appropriate the use of a learning system that combines Internet and digital media with established classroom forms that require the physical co-presence of teacher and students, i.e. the blended learning. In this contribution the authors make a proposal of implementation of virtual technological tools in non-presential activities with the aim of building a blended learning pedagogical framework for the subject "Chemistry", which is being taught in the first year of the mathematics degree at the University of Alicante (Spain). Two virtual tools were selected for the mentioned purpose: video-tutorials and virtual laboratories. Both were implanted in a complete teaching methodology that, properly integrated with presential lectures, pursues the two main objectives that follow: i) be a solid reinforcement of the concepts developed in class and ii) have enough scientific entity to launch new ideas on the less developed items in the presential lectures.

Keywords: Blended learning, self-learning activities, virtual technological tools, laboratory video-tutorials, virtual laboratory.

1. INTRODUCTION

With the aim to ensure comparability in the standards and quality of higher education qualifications in Europe, a series of ministerial meetings and agreements between European countries started in 1999, named the Bologna Process after the place it was proposed, the University of Bologna. It means the creation of the European Higher Education Area (EHEA) (Romanian Bologna Secretariat, 2010), based on cooperation between ministries, higher education institutions, students and staff from 47 countries, with the participation of international organisations.

With its implementation, a new concept of teaching has to be considered: the interactive teaching, in which the student must take an active part. Moreover, one of the key aspects in the EHEA methodology implementation is the use of an evaluation system which allows the active participation of the student during the learning process (López, 2009; Sanmarti, 2007). This implies the use of a continuous evaluation that brings information, both to the student and the teacher, about the students' progress and understanding of the topics exposed.

Therefore, the new educational models are based on integral formation, connexion with enterprises and, most important, improvement of personal talents through development of instrumental, interpersonal and systematic competences. For a proper teaching-learning environment it is in consequence mandatory to follow an integral educational program that considers the face-to-face instruction and self-learning activities as a whole, in the understanding of the utmost importance of the out of class students' time (Fernandez March, 2003).

Traditional lectures and final tests to evaluate the students must be transformed into interactive lectures, combined with self-learning activities on the students side and a continuous evaluation, where the final test is just a part of the global assessment. Thus, a more objective and complete comprehension of the subject can be achieved, and the student's success would depend not only on the ability of the lecturer but also on their own capacity of work, dedication and interest.

From this point of view, it seems more than appropriate the use of a learning system that combines Internet and digital media with established classroom forms that require the physical co-presence of teacher and students (Bonk & Graham, 2006; Friesen, 2012), i.e. the blended learning.

For about ten years, the University of Alicante has been developing a Teaching Research Program (TRP), known as Teaching Network (Instituto de Ciencias de la Educación, 2003), which objective is to improve the teaching quality and adapt its methodology to the European Higher Education Area (EHEA). Our particular experience began at 2006, with a project called "EHEA Teaching Network for the Geological Engineering first year", with the aim to establish and try a new methodology for teaching the subject "Chemistry" in the first year of Geological Engineering. The experience was continued at 2007 with the project "EHEA Teaching Network: Design of new materials for the Geological Engineering first year", going into detail about the materials used for teaching the above mentioned subject. The meetings of the network members allowed us to share different points of view and analyse different ideas which helped everybody to achieve better results with the students.

Thanks to these Teaching Networks, when in 2010 the EHEA began to be implemented at the University of Alicante, we were ready for work.

That year, at the Department of Inorganic Chemistry, a Teaching Network was created to coordinate the methodologies used in the different subjects taught by the Department professors, at the first year of the new degrees (Chemistry – Mathematics Degree, Chemistry II- Chemistry and Geology Degree, and Applied Inorganic Chemistry - Chemical Engineering Degree) (Alcañiz-Monge, Illán-Gómez, Román-Martínez, Sánchez-Adsuar & García-García, 2011). At the same time, every Degree created a Teaching Network for its own first year.

The experience obtained working at the "Mathematics Degree first year network", and the methodology followed for teaching the subject "Chemistry" (taught in the first year of the mathematics degree at the University of Alicante, Spain) to our students has already been explained (Sánchez-Adsuar, 2012; Sánchez-Adsuar, 2013).

As a continuation of our effort to improve the comprehension of the students, in this contribution we propose the implementation of some virtual technological tools during the self-learning time of the above mentioned subject "Chemistry". For that purpose, two virtual tools have been selected: laboratory video-tutorials and virtual laboratories. Both have been considered in a complete teaching methodology that, properly integrated with the face-to-face lectures, pursues the two main objectives that follow: i) be a solid reinforcement of the concepts developed in class and ii) have enough scientific entity to launch new ideas on the less developed items during the face-to-face lectures. These technological resources have been selected based on the following criteria: i) adequacy of the proposal to the context, available resources and students profile; ii) coherence, understood as the congruence between proposed actions and scope of each activity; iii) functionality of the planned activities in order to solve specific needs; iv) relevance, since the proposed activities must cover an important spectrum able to give answers to detected needs; v) sufficiency, understood as the level of achieved development on the bases of some defined minimums of quality and quantity; and vi) satisfaction, given that students must feel comfortable in the balance of preliminary expectative, employed efforts and achieved results (Ndirangu, 2007).

2. DEVELOPMENT OF THE PROPOSAL

As above mentioned, in previous papers [9, 10], the methodology followed for teaching the subject "Chemistry" and the evaluation and assessment of the student learning was explained.Following the EHEA idea, the teaching methodology includes both face-to-face instruction and self-learning time. As a summary, Table 1 shows the learning times dedicated to every teaching activity and the methodology used in each of them.

Table 1. Learning times dedicated to every teaching activity and the methodology used in each of them.

Teaching activity	**Methodology**	**FFI[1]**	**SLT[2]**
Interactive lectures	Lectures supported by the use of blackboard, power point presentations, videos and connexions to suitable web links	33	59
Problems resolution	Resolution of chemistry problems, using the suitable informatics supports.	18	18
Virtual laboratory	Experimental approach to chemistry, showing the reactivity of the chemical elements and compounds, as well as the basis of a chemistry laboratory.	6	6
Seminars	Preparation and exposition of a monographic work and its power point presentation	3	7
Total time (hours)		**60**	**90**

[1]FFI: face-to-face instruction and [2] SLT: self-learning time

According to this methodology, and with the aim to improve the student comprehension of the subject, blended learning has been introduced. Overall, the advantages of this methodology are (Garrison & Kanuka, 2004; Alexander, 2010):

(i) Facilitate a simultaneous independent and collaborative learning experience

(ii) Contribute to student satisfaction and success in courses.

(iii) Improve access to as well as student attitudes towards learning.

(iv) Improve communication between lecturers and students.

The virtual technological tools proposed, following the objectives above mentioned, are laboratory video-tutorials and virtual laboratories. Both are included in the virtual laboratory section, and their implementation is explained below.

2.1. Laboratory video tutorials

Until the past school year, laboratory training was undertaken with a combination of laboratory experiences videos, connexions to suitable web links, and use of blackboard (face to face instruction). This methodology was chosen based on the following criteria:

(i) Time optimisation: considering the limited time dedicated to laboratory training (6 hours for each face-to-face instruction and self-learning time), the methodology followed allows the students to view and discuss many more experiments than they would if they had to carry them out in a laboratory.

(ii) Prevention of potential danger in the laboratory: as first year students are not trained enough in laboratory skills, the use of videos and web links allow them to experience important but dangerous chemical reactions, as ammonium dichromate volcano (Fig. 1) or obtaining of chromium through aluminothermic reactions (Fig. 2).

Fig. 1. Ammonium dichromate volcano reaction.

The use of laboratory video tutorials that we propose in this paper would change the teaching methodology used until now:

(i) Instead of showing videos and web links to the students during the face-to face time, they would be embedded in the web media used to interact virtually with the student ("campus virtual", web environment created by the University of Alicante Data Processing Centre).

(ii) Instead of explaining face-to-face the steps of the reaction showed, the student should watch the videos and, using all the information obtained through the interactive lectures and the bibliography, try to explain the reactions observed.

(iii) Instead of having the right answer directly, during the face-to-face time their conclusions would be contrasted among them and with the teacher results.

The benefits of this change in the teaching methodology would be:

(i) Increase in the reinforcement of the concepts developed in class, through the increase in the student self-learning effort.

(ii) Improve the ability of the student to correlate different concepts with the aim to find the solution to a practical question.

(iii) Enhance the critical ability of the student, through his results contrast with those of his classmates.

(iv) Allow the student to connect the different learning methodologies.

Fig. 2. Obtaining of chromium through aluminothermic reactions

2.2. Virtual laboratories

The complex teaching-learning process of laboratory training needs sometimes the finding of new methodological tools that help to achieve the right objectives in the context of the EHEA framework. One of these tools that have been thought to be effectively positive is the implementation of virtual laboratory sessions for the self-learning time. These tools, classified as ICT (Information and Communication Technologies), are of the outmost importance for the students training, since they reinforce the necessary sense of responsibility in the student and provide her or him with the necessary learning autonomy that she or he must develop through life. The students, in this way, 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. 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.

According to 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 & 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):

(i) Increasing methodological diversity.
(ii) Increasing accessibility and flexibility.
(iii) Promoting the student’s leading role.

(iv) Improving the presentation and comprehensiveness of certain types of information.

(v) Encouraging cooperative work.

(vi) Improving individual work.

(vii) Gaining access to new environments and situations.

(viii) Optimizing resources and costs.

These ICT technological tools allow the student to enhance her or his 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

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 (Alba Pastor, 2005; 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.

2.2.1. Materials

Among the large amount of tools for Virtual Laboratories which are available in the market (or freely on the web) we have selected 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 (Woodfield, Asplund & Haderlie, 2009) (Fig.3). 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. 4 and Fig. 5 are snapshots of general views of the inside of the laboratory to which VCL tool gives access.

Fig.3. 'Virtual General Chemistry Laboratory' book cover (ISBN: 978-607-442-210-8) (Woodfield et al., 2009).

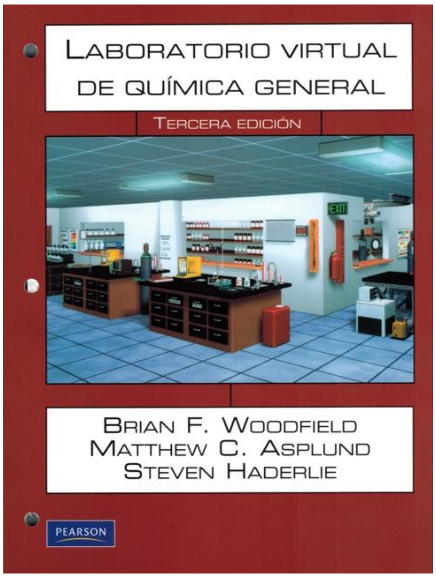
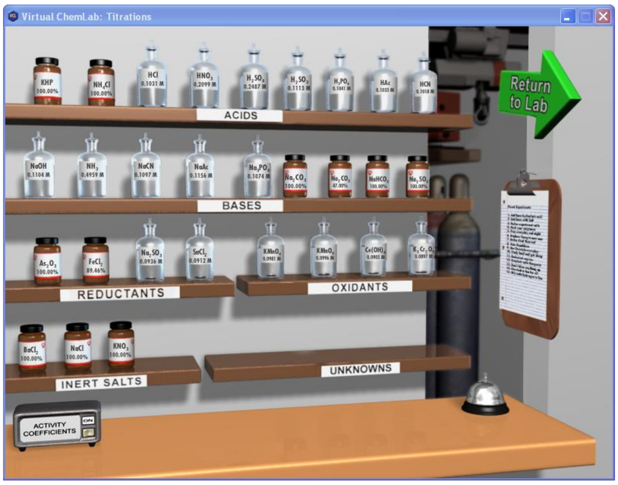


Fig. 4. Overall look of the Virtual Chemistry Laboratory, in which different work areas are shown (Woodfield et al, 2009).

Fig. 5. The Virtual General Chemistry Laboratory provides a realistic environment where all sort of reagents can be found in different storage facilities (Woodfield et al., 2009).



This book is a complete tool with a package of realistic and complex simulations that encompasses the different experiences that can be carried out in a general chemistry laboratory. It brings a virtual environment in which students are free to make choices and decisions similar to those confronted in an actual laboratory. The feeling of experiencing a good practice (or a malpractice) is so realistic that the user (students) tends to feel responsible of what happens in the laboratory (with the advantage of being out of any danger). 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.

2.2.2. 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).

2.2.3. Procedures

We propose to explore the VCL tool in two aspects:

(i) On the one hand, it can be a complementary tool for the explanation of new chemistry concepts in the classroom (FFI). To that end, the VCL tool can be used for the execution of several experiences in class, which might be afterwards followed by a proper debate on the treated issue.

(ii) On the other hand, the program can be distributed among a limited number of students, so they can assess from home its utility as reinforcement to the practical sessions of the different subjects and to the concepts seen in class. Of course this depends on the number of students per class, and it is conditioned to treat with groups of, at the most, ten students.

2.2.4. Expected outcome

Although the expected outcome of the implementation of the VCL tool is largely positive, it must be put under consideration on different aspects: i) VCL must be checked inside the classroom, based on teacher's 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) VCL must be checked out of classroom, based on student's experience in using this tool at home.

We can make a –a priori- balance of expected advantages and disadvantages of using this tool within the different aspects commented above. 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 Table 2.

Table 2. Compilation of expected outcome in the implementation of the VCL tool, 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	– misjudgment of the laboratory circumstances

3. CONCLUSIONS

The implementation of virtual technological tools in non-presential activities for the subject "Chemistry" will lead to a blended learning pedagogical framework with many benefits for the students.

On one hand, the use of laboratory video tutorials would:

(i) Reinforce the concepts developed in class, through the increase in the student self-learning effort.

(ii) Improve the ability of the student to correlate different concepts with the aim to find the solution to a practical question.

(iii) Enhance the critical ability of the student, through his results contrast with those of his classmates.

(iv) Allow the student to connect the different learning methodologies.

On the other, virtual laboratories advantages in the classroom are also multiple:

(i) Provide a lot of visual information (hence, direct reception)

(ii) Interactivity (it holds both the teacher's and the students' attention for the achievement of the different steps required for the accomplishment of a experience)

(iii) Obtaining immediate results, exempts from the circumstantial problems which often arise in an actual laboratory.

However, this tool is not exempt from some disadvantages. Both advantages and disadvantages of using VCL have already been exposed in Table 2.

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