LEARNING PHYSICS LABORATORY WITH VIRTUAL OSCILLOSCOPE

P. Martínez-Jiménez, M. Varo, A. Pontes-Pedrajas, M.C. García, G. Pedrós and M.S. Climent-Bellido

Department of Applied Physics, C-2 building, Campus of Rabanales, 14071, Córdoba, SPAIN. Telephone: 34 57 212085, Fax: 34 57 212687, e-mail: fa1majip@uco.es, f72vamam@uco.es, fa1popea@uco.es, fa2gamam@uco.es, fa1pepeg@uco.es.

Abstract

This report describes the results of an investigation on the teaching of Physics Laboratory in which real and virtual oscilloscopes are implemented and coordinated. Firstly, our research group developed a virtual oscilloscope (VO) as a multimedia tool for Microsoft Windows. This application consists of a complementary tutorial (see tutorials in www.uco.es/grupos/labvirtual) and a simulation. With the last one we can obtain on the virtual oscilloscope screen, the same response to any electrical signal we work with as in a real one. Signals are introduced from the outside into the virtual oscilloscope by a virtual generator and the methods of work in virtual and real laboratories are identical. In order to optimize the realism of the application, all the devices have been designed reproducing the ones we have in the experimental laboratory of our department.

With this software, we have carried out an educational experiment aimed at assessing its influence on the learning of some basic physics laboratory techniques. This research has been carried out with first-year students at the Superior Polytechnic School of Córdoba (Spain), with outstanding results when compared to those students who had not previously worked with the VO. This observation provides support for asserting that the use of VO helps students to understand better the techniques and basics concepts used in laboratory work. The use of this program particularly forwards the progress of those students with high learning difficulties

Keywords: interactive learning environments; multimedia/hypermedia systems; simulations; teaching/learning strategies; virtual reality.

INTRODUCTION

Many studies (1-3) have shown the usefulness of computers as an interactive communication means permitting access to all kinds of information (texts, images, different types of data, graphics, etc.), as an instrument for problem ***solving***, as a tool for carrying out simulations of physical phenomena and experiments, or to measure and monitor laboratory experiments (4,5). It should also be noted that the computer can be used to administer and direct class tasks, to store and analyze educational process data, to carry out learning evaluation or to diagnose deficiencies and propose remedial activities (6).

In view of all these advantages, computers began to be used in education a few decades ago and great expectations were placed on their didactic applications, although the results have not been as good as was hoped. At first, it ***was used*** **program teaching** based on ***behaviorist*** theories, but did not prove to be very satisfactory. Later, computer applications in education were greatly extended and, in most cases, a technological educational model was adopted in which it was assumed that the learning process could be improved as the means and procedures for presenting the information went on improving. However, ***extensive research on*** alternative concepts and learning difficulties ***has suggested that it makes sense*** to take a constructivist approach to science education. It suggests a science learning which might take into account the influence of the previous ideas students have as a result of the preceding stages of the process (7).

This educational perspective can also be transferred to the computer-assisted teaching field. To be specific, some works published have underlined the interesting possibilities offered by computer programs to promote the understanding of concepts by means of conceptual change processes (8,9). We believe that computers can be of use in fostering other activities, such as the ***design of*** experiments and the ***solving*** of problems, which are also of great educational value in physics. In the constructivist approach to science teaching, it is considered that these kinds of activities can be conceived as investigation processes (10). By ***applying*** this ***idea*** to the educational technology area, we believe that the computer can be used as an instrument to analyze the previous knowledge of students ***on*** a topic, help them ***¿propose?*** their own hypotheses with regard to a problem, make a selection between several ***possible solutions***, analyze results, draw conclusions, etc. ***Thus***, the computer can be a tool for helping students to be ***active participant*** in their own learning process (11,12).

From this perspective, our ***research*** has focused on the development and evaluation of tutorial systems ***that*** includ***e*** several modules (diagnosis of previous knowledge and ideas, problem ***solving***, simulations, self-evaluation, etc.). From an educational point of view, the main didactic utility of these tutorial systems is that, when compared to other methods and other teaching aids, they offer simulations of physical phenomena in which the student can modify the independent variables of the problem and analyze how the remaining variables change (13). We ***belive*** that experiment and process simulation is one of the most interesting activities among computer applications in science education. ***Furthermore***, this aspect is constantly improving, at the same time as the graphic possibilities and the processing speed of computers are ***increasing***.

The main advantages of educational-type simulations are: the presentation of situations which in practice ***can not to be reproduced (¿irreproducible?)***, the idealization of experimental conditions, the presentation of situations requiring very complex equipment, the presentation of ***dangerous processes***, ***and*** the manipulation and control of variables. **In adition, they can be a low-cost alternative** to the real processes simulated by the computer (14-16). The development of virtual laboratories ***also has relevance to*** computer physical applications in the treatment of a broad spectrum of problems of educational interest (17-19).

Among the specific aspects of the use of multimedia resources in physics teaching, especially related with this current work, two facts should be ***emphasized.*** Firstly, that the use of appropriate educational software ***can help*** to improve the performance of students when carrying out practical work in the laboratory, as has been demonstrated in previous research work (20-21). Secondly, the important role that complementary activities have in the teaching-learning process, specially when we work with scientific concepts and procedures, can be emphasized using multimedia resources as it has been shown in theoretical (22) and empirical (23) studies. This indicates that it would be necessary to combine the use of virtual laboratories with the carrying out of activities aimed at encouraging thoughtful learning in students working with simulations (6).

In an experimental laboratory, oscilloscope is one of the most useful measurement instrument since almost the whole magnitudes can be transformed by transductors into electrical signals. It evaluate voltage but it is also used to quantify frequencies, amplitudes, etc. because of it versatile to visualize periodical and no periodical signals.

The use of oscilloscope in experimental labs is essential to measure and determine not only electrical signals but also other kinds of signals. However, students find it as a very complex tool, and it is very difficult for them to understand its physics basis and it basics use. In order to make students assimilate their work in labs, lecturers might spent a lot of time explaining the whole instrument so it would be very difficult for them to explain properly the theoretical basis of the experimental process proposed.

Long time ago, lots of researching groups have developed software which implement the studies of oscilloscopes. However, most of them, in spite of being very good, use English as work language and do not let its users work in the same way as in a real laboratory, it means, they can not modify the commands or change the scale.

Because of all we have exposed, we have developed a program in which a virtual study of the oscilloscope has been carried out explaining its basis, characteristics, components and how it must be used in some practices. With it, we have aimed to obtain in its screen the same response we would have in a real one by manipulating it correctly.

EDUCATIONAL CONTEXT AND GENERAL AIMS OF THIS RESEARCH WORK

The first courses taught at the University of Cordoba (Spain) are overcrowded (pupil/lecturer ratio is approximately 150:1) and this implies that it is not possible to give the ***lecture*** and ***laboratory*** classes simultaneously. ***Thus*** the class is subdivided into groups of 30 for ***participation*** in the laboratory. What is more, the lecturer finds it impossible to individually tutor students.

Over the years, our ***research*** team has developed some computer tools for numerical simulations ***for solving*** problems in physics, although not including experiment***al*** work. These programs have been used as ***suplementary*** teaching aids in traditional lessons (13, 19). Our experience, under the working conditions previously cited, showed that students ***improved in conceptual understanding*** and problem ***solving*** (16) but, ***until***l now, we have not ***dealt with*** the learning of experimental scientific procedures, in physics, with computer programs.

For that reason, we carried out an educational project ***involving*** the development, application and evaluation of a virtual oscilloscope (VO), which ***demonstrates*** basic step-by-step laboratory ***procedures*** and ***simulates real laboratory activies*** (24). The general ***goals of this project*** were:

- to relate the theoretical-practical aspects of physics teaching, since in the tutorial students are able to consult all the information available on concepts
- to know the instruments and processes necessary to understand the phenomena studied in each simulated experiment

- ***to improve the self-learning process of students and encourage the acquisition of scientific "habilidades" in the development of experimental activities***
- to ensure that students obtained sufficient information on ***how*** to use the most important apparatus in a physics laboratory.
- to ***encourage*** a critical analysis of the experimental results on comparing the virtual laboratory data with those obtained in real experimentation.

To achieve these ends, we have taken into consideration the results from the evaluation of physics laboratory ***student*** works in previous years . A ***program*** was thus developed which specifically aspired to aid students to overcome the difficulties of the conceptual and procedural learning observed in the previous stage. A program of activities was also set up to direct the work of the students when doing the simulated experiments.

In this work, we shall present the design process of a first program prototype, together with a summary of the results obtained ***from*** its ***evaluation***. We shall also analyze the characteristics of the present version of the program and its possible educational applications.

The educational experiment was carried out with our Engineering students, although in fact lecturers in other subjects (such as Physics) have shown an interest in the introduction of this program into their classes so that in the near future data will be available to enable us to ***compare results across different populations of students.***

DESCRIPTION OF THE SOFTWARE

The software used in the experiment was developed in a Windows environment, using a multimedia programming tool (microsoft vb 5.0).

The program can be applied with a PC or through ***a local channel (red local de ordenadores***) and is distributed via the University of Cordoba's web page in Internet (http://www.uco.es/grupos/labvirtual), after been applied by e-mail. The tuturial can be looked up in that web with a video that shows the performance of the oscilloscope. ***A windows 98 operating system, or higuer, is required.***

All the application screens have similar features and interfaces, which are as intuitive as possible, ***to minimize navigation difficulties*** in the program. Nevertheless, there are support screens to show the meaning of the controls used, and access to each screen is assisted with an explanation.

The software has ***a important aspect***: ***interactivity***. ***The interactivity allows*** users ***to*** decide at each moment the course of their learning process and they are able to modify the experiment being done ***in the*** simulation.

The ***program*** consists of two different, ***but interconnected,*** parts: Tutorial, Virtual laboratory. Even though each part can be carried out independently, it is advisable to follow that order, at least in the initial use of the software.

Tutorial module

In this module, different concepts and basic principles of oscilloscope related with the topics dealt with in the VO are explained by a illustrated and animated HTML tutorials. The knowledge acquired by the student in this section will be used, and thus reinforced, in the Virtual laboratory section. These tutorials are accessible from any point in the software, using the general index. Furthermore, since the tutorial has been programmed in HTML, it can be directly consulted in the web without the software. The students can repeat this section as many times as they like and whenever they wish (figure 1).

In the theory section, the student will find a menu, where he/she will be able to choose the subject he/ she wishes to study by a mouse click on the corresponding button . The tutorial includes five different sections: Introduction, terminology, performance, controls y measurements techniques.

Experiment simulation module

This second module is the most interesting one in the program from an educational point of view, since it permits students to perform simulated experiments following an activity program-guide and to obtain similar results to those obtained in a real laboratory. It is a work screen which initially shows a gray screen with a menu on the top that includes: analogical oscilloscope, digital oscilloscope, connections map, colors map (so that the user could choose the color of each signal), lines width, tutorial access, help (in html), print. Below it, there are some fast access buttons. In addition to that, any selection can be made with an emerging menu that appears after pushing the second button of the mouse.

Firstly, it is possible to gain access to the study of the digital oscilloscope. On this screen two functions generators and an oscilloscope have been introduced (figures 2,3,4 y5). The student can look up the connection map in order to check how to link up the instruments of work when working with an experimental laboratory.

The student must work according to the following guide: First, switch on the first generator pushing the on/off button with the mouse, later, select the frequency interval and the particular value of work of the magnitude. Pressing on voltage and phase button he or she can introduce the output wished for the first generator.

In order to see the signal, the oscilloscope must be switch on with the mouse and the canal A must be selected. As it might be done in experimental laboratories, each control must be correctly fit so as to obtain a perfectly measured signal.

To see two signals, work with the second generator in the same way that with the first one and connect it to canal B, fitting correctly all the buttons and controls. The signals given by the generator can be squared, triangular or ¿sino kind?

The student can quantify with the oscilloscope voltages, periods and, consequently, frequency of the individual signals. Selecting “dual” button he or she can see simultaneously both of the signals and measure the differnence on phases between them. Choosing ADD he can get the signal result as the sum of the previous ones.

As far as pedagogy is concerned, the fact that students can observed the modulated frequency signal is very interesting because it let them check that lineal oscillations with similar frequencies but not necessary the same shape, generate, when superimposing, a new signal with the same direction and modulated frequency and that the phenomena is very similar to the one of mechanics oscillations which happens to be much more difficult to see in a real laboratory.

Finally, when X-Y mode is selected, the user can obtain Lissajauss figures and see how their shapes change whe he or she modify the relation between the frequencies or phases of the two signals he or she is working with.

Analogical oscilloscope also has a connection to an outer tigger generator.

The most important aspect of this software is that the student works in the same way as in real lab except for the fact that he or she has to push or vary magnitudes of work with the mouse.

As a second option, the software let the user work with the digital oscilloscope (figure 6) and the method of work is the same as the used for the analogical one. On the screen only the oscilloscope is visualized. So as to introduce outer signals there are two different options. The first one is to introduce them by exterior generators which have the controls: Frequency selector, amplitude, offset in CC, and kind of signal, difference of phase or noise. They work in the following way: First, it is necessary to select the frequency, amplitude, offset, kind of signal, difference of phase and noise that is required. Secondly, the user must push the button called "*Aceptar*" to generate the signal, go out of the function generator and go back to principal screen of the digital oscilloscope. In the same way the user must work is outer tigger generator is chosen.

It is also possible to accede very quickly to different options with special combinations of keys. The use of keys with the brief method is the fastest way of select each of the menus the application has. Only by pushing a key or a combination of them a concrete menu will be executed. For instance, Ctrl+S⇒Go out of the application, Ctrl+P⇒Print the oscilloscope that in that moment is visible, F3⇒See the sets of the analogic oscilloscope, Mayus+F3⇒See the connections analogical map.

Help

The software includes a Help developed in HTML that is structured and designed as the tuturial. This help is always available and the user can accede to it from any part of the program. It solves any kind of doubt about all and each of the parts that the software includes.

In order to make the work easier to the users, an interactive help has been also created. To use it, first, with the mouse, we must push on the help icon placed on the right side of the ¿tool bar?. After doing it the closed book that represent that help, will unbend.

After it, we only have to pull the mouse pointer onto a determined control. Then, an automatic screen will appear with the information about this function and how it must be used. For example, we can check that when we pull the mouse onto the sweep-time div control of the analogical oscilloscope, a window appears on the center of the computer screen that contains the information about it. Pushing onto any place of the screen will suffice in order to close that window.

WORK METHODOLOGY

The software described above is simple to use and, additionally, contains a help module, which provides enough information for the user to handle it satisfactorily. However, in order to try to improve this software's educational effectiveness, we have designed a program-guide of activities, which direct the students' interaction work with the computer, to attempt to encourage an active and thoughtful learning process (6).

This program-guide can be presented as an additional document in a text window of the Windows environment or as a written document. The study shows the guide program which is given to the students to make their simulated practice.

The following is a brief description of this document's structure and some of the activities it contains.

The aim of the first activity proposed is to make a previous evaluation of the knowledge of the students by a questionnaire. The lecturer, after having them evaluated, recommend the students to see the results of the initial evaluation and to take notes of the diagnosis made to try to overcome the deficiencies in the previous knowledge of the theme.

After that, work on the virtual oscilloscope must start, a general review of the VO program's tutorial module should be carried out in order to answer different questions, like the following (for instance): What does produce the signal on the oscilloscope screen? Why must be an oscilloscope used to measure voltages in different components of an c.a. circuit instead of a polymeter? Why can the oscilloscope only measure frequency values below 150 Mhz?

The third global activity, made up of a large set of specific tasks, consists of accessing to the simulation module and performing virtually some concrete experiments such as : a) Measure of the highest voltaje in the wave function given by a generator. b) Measure of the period of the signal which appears on the oscilloscope and calculation, according to that, of the frequency of the generator, c) quantify of the difference of phase between the two signals on the oscilloscope produced by the generator, d) Determine the frequency of the two signals according to the one of the frequency modulated signal that can be observed on the oscilloscope when using the sum mode, e) determine the frequency of two signals from the Lissajaus figures.

All these activities must be made according to the software guide given to the students and answering various questions proposed to the students on this theme: why is it necessary for the signals of the generators to have the same frequency when we want to measure the difference of phases between them in dual mode? How must the frequency of two signals be so that a frequency modulated signal can be achieved by suming them? What is the physical explanation of X-Y mode?

After running through this program and doing the practical activities suggested, students are advised evaluation and answer the new questions que se les proponen there to evaluate the learning concepts acquired during the work session. Finally, students are asked to meditate on the results obtained in the final evaluation and to formulate their personal conclusions on the software's educational value.

For students using this program, the tasks of the greatest didactic interest correspond to the development of the third global activity of the program-guide, in which students are invited to reflect and analyse what they are observing in the simulation, at the same time as following the steps demonstrated in the software.

DEVELOPMENT AND EVALUATION OF EDUCATIONAL EXPERIMENT

Experiment design of the research work

As well as developing didactic software, we believe it necessary to apply the programs elaborated in real educational contexts and to evaluate their influence on the acquisition of scientific knowledge through educational research processes. In that sense, we have therefore proposed one main research objective: to contrast the results in training acquired by first-year students in developing and perfecting experiment techniques when working with real and virtual laboratories, and when they only did so with real laboratories.

In order to make a quantitative assessment of this main aim we have divided it into four subjective or specific aims related with the learning of concepts and procedures carried out by students when doing chemistry laboratory work with or without the aid of the software described above. These specific objectives are:

1. To learn about the characteristics of the most important chemistry laboratory apparatus and to acquire skills in the setting up and operating of the practical exercices.

2. To master the basic operations performed in a chemistry laboratory: extraction, distillation, precipitation, etc.

3. To acquire the necessary knowledge to enable them to select the appropriate technique to resolve mixture separation problems.

4. To relate the theoretical-practical aspects proposed with those experiment tasks.

To assess the achievement of these objectives, this program was used with 1st year technical engineering students and for two years running. In the first stage, data was taken from two groups of students who followed a traditional teaching method {control groups GC1 (n=72) and GC2 (n=67)}, based on a theoretical exposition and experiments in the laboratory. In the second stage, data was taken from two other student groups who had been given the same theoretical-practical contents using the virtual chemistry laboratory as a complementary tool to introduce them to the real laboratory {experiment groups GE1 (n=65) and GE2 (n=70)}.

The average age and university entrance mark of both samples did not show any statistically significant differences, so that it can be assumed that their prior knowledge and learning abilities were the same. A comparative study of the learning results from the control and experiment groups was made from the data obtained by the use of several evaluation instruments to be explained later.

In both the control and experiment groups, the collection of the learning process data of basic chemistry laboratory techniques was conducted during each academic year when the experiments had been finalized. In this research work, only the data corresponding to one particular experiment concerning the laboratory techniques needed to obtain the extraction of caffeine from tea were analyzed and compared. In subsequent studies, we shall attempt to extend this work methodology to the practical and simulated performance of a greater number of laboratory experiments, as and when we dispose of other simulation programs being developed at present.

Description of the process followed in the two experimental stages

To carry out the study made with the control groups (GC1 and GC2), several laboratory experiments were prepared, providing the students from these groups with prior theoretical information and a document in which the tasks to be done for the development of these experiments were outlined.

The educational contents developed in this first study can be broken down into the following three sections: laboratory apparatus (glass, metal, etc.), basic operations in the chemistry laboratory (preparation of solutions, distillation, filtration, extraction,etc.) and experiments incorporating basic processes (extraction of caffeine from tea leaves, etc).

On finalizing this process, students will have given in a written report in which they show and analyze the results obtained, reach conclusions and answer diverse questions related to their interpretation of the processes performed in the laboratory. Then they do an evaluation test based on a written questionnaire, in which several questions related to the learning of the above concepts and procedures are posed.

After developing the virtual chemistry laboratory, we repeated the previous experiment, using this tool as a complement, with the students of the GE1 and GE2 experiment groups. The educational contents with respect to the concepts and procedures of the second experiment process were the same as those carried out in the control groups. GE1 and GE2 worked in small groups during several sessions, first with the virtual laboratory and then they went into the real laboratory.

The time devoted to the experiment was similar in both stages as the experiment group students substituted the theoretical study for the first work session with the computer program, in which they were able to study the information available in the tutorial module. Other advantages shown in using the software are the ability to rapidly repeat an experiment simulation however many times it is required and the possibility of receiving a diagnosis on the level of learning at each moment by accessing the evaluation module.

When working with the virtual laboratory, the students follow the program instructions: they drag the icons of the laboratory material window to the simulation window, enter data on the experiment's quantitative variables, select the type of basic operation to do at each moment, observe the results of the successive processes, taking notes on the latter, and discuss the questions posed in the activity program-guide.

After working with the software, the students from the experiment groups did the same experiments as the control group students, with the advantage that they were already familiarized with the procedures needed to carry out this work. Finally, these students also wrote reports on the work done in the laboratory.

Evaluation of the experiment

To make an evaluation of the development of this educational experiment, in order to permit us to find out the degree of satisfaction in the achievements of the educational objectives proposed, an evaluation was made of the learning acquired by each of the students of control groups GC1 and GC2 and of those in the experiment groups GE1 and GE2, account being taken of the following aspects:

a) skills in setting them up and the actual carrying out of the experiments,

b) the quality of the laboratory work reports drafted by students at the end of the experiment, in which the results obtained from each of the experiments and the answers to the questions posed in the work guides are shown.

c) the results of an experiment in which a practical problem was proposed, namely the separation of mixtures, for which students selected an appropriate technique.

d) the results of a written test made up of several questions in which students have to demonstrate that they can relate the theoretical-practical aspects involved in the study.

The evaluation process was the same in both the control and experiment groups. To assess the level of learning reached by each student in the four educational objectives formulated, a global numerical grading system was adopted, of between 0 and 10 points, in which were incorporated data from the aspects cited above (a, b, c and d) and which served to grade the specific performance achieved for each objective. Additionally, to evaluate the overall performance of each student, the marks corresponding to the four objectives were added together so that each student had a marks capacity of between 0 and 40 points.

From these partial marks, overall categories or learning levels can be defined and it is possible to plot the differences in graphics and reach conclusions about the carrying out of the experiment, as will be seen later. Statistical processing can also be done on the performance differences between the groups. With the evaluation data corresponding to the partial marks of the four objectives and the global marking, obtained from both groups, various contrast tests were made to analyse whether the differences between these groups were significant from a statistical point of view. Namely, since the quantitative data considered in this study did not fulfill the restrictive conditions of the application of the statistical parameter tests, it was decided to apply the Kruskal-Wallis test, whose results are commented on later.

Analysis of results

For our study of the evaluation results for each of the objectives, we took the partial marks assigned to the students in the different groups and, for each one, four categories or levels of learning were established according to the following classification: category I corresponded to very low marks (deficient learning), category II to average marks (fair or semi-acceptable learning), category III to high marks (good learning level) and category IV corresponded to very high marks (very good learning level).

We can see that the results obtained by both groups are fairly similar. On comparing the results from GC1 and GC2 in each of the four objectives, it was observed that there were some differences in the different categories, but IN the statistical contrast study made between the average marks of each group no statistically significant differences in any of the objectives was noted. This means that both groups had developed a similar learning process and had reached a similar performance level. However, in both cases it was observed that categories III and IV showed much lower percentages than categories I and II, so that it can be deduced that the amount of knowledge acquired by the control groups was not particularly good, although it can be considered as being acceptable to judge by the percentages reached in category II for each of the four objectives by both groups.

In the experiment groups, the same evaluation process was followed as in the control groups and the same analysis procedures and data presentation were applied. If we consider the results obtained by the students in GE1 group and group GE2, we can state that the results obtained by both groups also present a similar allocation of percentages to the different categories of the objectives evaluated. Moreover, in the statistical contrast study made between the average marks of each group, no statistically significant differences were noticed in any of the objectives, which was logical because both groups had the same initial characteristics, had carried out a similar study process and had reached a similar performance level.

In order to analyse the influence of the methodology followed in the experiment groups, a comparison was made of the results of these groups with those previously obtained by the control groups. In this comparative analysis, there were several interesting facts.

For instance, on analysing the data of the first and second objectives, it was observed that the percentages of categories I and II were much higher in the control groups than in the experiment groups, which suggests a shift in the number of students from groups GE1 and GE2 who had achieved these objectives compared to those who had not done so in groups GC1 and GC2. Likewise, on applying several statistical contrast tests, significant differences were noted between the average values of the marks obtained in objectives 1 and 2 in the experiment groups. This led us to us consider that the use of the software described, together with the laboratory experiments, had contributed to improving knowledge about the apparatus and basic operations in the laboratory in the experiment group of students.

With regard to the third objective, the comparative analysis shows us that the results were also better in the experiment groups than in the control groups, so that it can be said that the second experimentation based on the use of software and the real laboratory favoured the development of the procedures and skills necessary for the resolution of the practical problems of mixture separation. In this third case, the statistical contrast of the average marks of these groups was not so relevant as in the previous objectives, but it also supplied statistically significant differences in the experiment group.

The results permit the making of an analysis of the results of the fourth objective, which is related to the resolution capacity of theoretical-practical questions on the aspects dealt with in the development of the experiment. In this case, relatively similar results in the four groups can be seen, characterized by the existence of higher percentages in the lower performance levels (I and II) than in the higher levels (III and IV) in the whole sample. In the contrast of average marks for the fourth objective, no statistically significant differences were observed between the different groups, except for group GC2 which obtained an inferior performance than the other groups due to the high percentage of individuals catalogued in level I.

The fact that groups GE1, GE2 and GC3 have similar results indicates that the use of the virtual laboratory did not have much influence on the producing of significant differences between the experiment and control groups with respect to the development of this objective, or that the questions posed had the same degree of difficulty for these groups.

Finally, we proceeded to evaluate and categorize the general performance of each student from the different groups, analyzing the set of data obtained throughout the experiment. To elicit an overall mark, the marks corresponding to the four objectives were added up, so that each individual had a mark of between 0 and 40 points. With the same procedure as above, four overall performance levels were established, as follows: L_I (overall mark between 0 and 10 or deficient learning capacity) , L_{II} (overall mark of between 10 and 20 or semi-acceptable learning capacity), L_{III} (overall mark of between 30 and 40 representing a good level of learning) and L_{IV} (overall mark of between 30 and 40, corresponding to an optimal or very good learning result).

We can also study the overall results of the four groups, with the percentages of the four all-round performance levels in each group. Firstly, it can be seen that the control groups GC1 and GC2 gave very similar results in the four levels. The same happens in the results of the experiment groups GE1 and GE2, although these groups present a better overall performance than the previous ones. Indeed, levels L_I and L_{II} show a higher percentage in the control groups with respect to the experiment groups (with variations OF close to 15% and 10%, respectively). On the contrary, in level L_{III}, the experiment groups obtained much better results than the control groups (with differences of over 20% between these groups). Finally, in level L_{IV}, all the groups reach similar, although low, percentages, which indicates that there were difficulties in achieving an optimal performance level both for the control groups and the experiment groups.

From a statistical processing of the overall marks of the four groups (with a Kruskal-Wallis test) we have deduced that, under working conditions in overcrowded classrooms and, therefore, with little tutoring and the impossible correlation of the theory and practical classes, the VCL favours the training of the average student, and causes a shift in results from the grades of “deficient” and “acceptable” to “good” in the experiment groups.

Finally, we believe that the similarity in the results obtained in level L_{IV} was due to the fact that in all the groups there were a few students with a superior level of specific knowledge and a greater interest in the subject, regardless of the teaching methodology.

Summary of results

To resume, some facts worthy of mention can be deduced from these results:

1) The evaluation process gave similar results in the two control groups GC1 and GC2, so that the system used can be considered as being reliable.

2) Similar results were observed in the experiment groups GE1 and GE2, using the same evaluation method, so that the learning process can be considered to be homogeneous.

3) Significant differences were noted between the degrees of progress of the experiment groups with respect to the control groups. The greatest differences were seen in level I (deficient learning) this being much greater in the control groups, and in level III (good learning), notably higher in the experiment groups.

From these facts, it can be concluded that the instruction process followed in the experiment groups enabled students to achieve a higher progress level than in the control groups and that the program used is a useful aid for improving the learning process. this would appear to confirm the results obtained in other studies which show the favourable influence of the use of simulation programs in the teaching of chemistry (20, 21) and of other sciences such as physics (23).

FINAL CONCLUSIONS AND CONSIDERATIONS

In this article, an empirical educational piece of research has been described, from which it has been deduced that the use of a chemistry experiment simulation program can be of use to students for a better comprehension of the techniques and basic concepts used in the laboratory work of this subject, *and can especially contribute to improving the work of those students who have the greatest learning deficiencies.*

After running through this program and doing the practical activities suggested, students are advised to go back to the VCL evaluation module and answer the new questions asked there to evaluate the learning concepts acquired during the work session. Finally, students are asked to meditate on the results obtained in the final evaluation and to formulate their personal conclusions on the software's educational value.

For students using this program, the tasks of the greatest didactic interest correspond to the development of the third global activity of the program-guide, in which students are invited to reflect and analyse what they are observing in the simulation, at the same time as following the steps demonstrated in the software (see examples of steps 9 and 14 in figures 3 and 4, respectively).

APENDIX 1

Programa guia

Abra el programa *OSCILOSCOPIO VIRTUAL* que se encuentra en la barra de programas.

Escoja el **osciloscopio analógico** (primer icono en la barra de acceso) para realizar la simulación.

- Encienda uno de los generadores de funciones (por ejemplo, el generador de la izquierda que está conectado al CANAL A del osciloscopio) pulsando el botón **ON/OFF**:
- Seleccione el ***tipo de señal*** (triangular, cuadrada o sinusoidal) que quiere generar. Por ejemplo, empiece estudiando la señal sinusoidal.
- Elija la ***frecuencia de la señal*** que va a generar. Para ello haga uso de los selectores de banda de frecuencia (botones superiores) y la rueda de ajuste fino de frecuencia situada a la izquierda. Por ejemplo, seleccione 100 Hz ó 200 Hz ó 300 Hz... (¡OJO!: que el valor sea superior o igual a 50 Hz ya que el osciloscopio no detecta señales de menor frecuencia).
- Elija la ***amplitud de la señal*** que va a generar. Para ello gire el control de amplitud. Por ejemplo, seleccione el valor de 2 V.
- Elija como ***desfase de la señal*** el valor 0.
- Elija como ***offset de la señal*** el valor 0.

• Encienda ahora el osciloscopio (analógico):

- Seleccione el ***canal*** que quiere visualizar: en este caso el CANAL A ya que es donde está conectado el generador de la izquierda.
- Escoja el ***modo DC*** o ***AC***.
- Para la función de ***disparo*** o ***trigger*** seleccione:

Slop +

SINC AC

CANAL A ⇒Compruebe que si seleccionamos el CANAL B para disparar no se ve imagen en la pantalla.

- Ajuste adecuadamente la ***base de tiempos*** (escala X): hasta observar una imagen de la señal en la pantalla en la que sea visibles uno o dos períodos de la misma.
- Ajuste adecuadamente la ***escala de amplitud*** (escala Y): hasta observar una imagen de la señal lo más grande posible sin que se salga de la cuadrícula.

• Realice las siguientes medidas y comprobaciones:

1. Amplitud de la señal. Para ello puede valerse (si es necesario) de los botones del osciloscopio que permiten desplazar hacia derecha/izquierda y arriba/abajo la imagen en la pantalla.

   Compruebe de esta forma el valor exacto de la amplitud de la señal que está proporcionando el generador de funciones.
2. Frecuencia de la señal. Para ello puede valerse (si es necesario) de los botones del osciloscopio que permiten desplazar hacia derecha/izquierda y arriba/abajo la imagen en la pantalla.

   Compruebe de esta forma el valor exacto de la frecuencia de la señal que está proporcionando el generador de funciones.
3. Observe qué ocurre si pulsa el **modo GD** del canal.
4. Observe qué ocurre al cambiar la frecuencia y amplitud de la señal proporcionada por el generador: detectará que hay que reajustar los mandos del osciloscopio (base de tiempos y amplitud) para volver a visualizar la señal
5. Observe qué ocurre al introducir un **DC offset** en la señal del generador: en el modo AC del canal no debe ocurrir nada, en el modo DC del canal sí deberá observar un desplazamiento vertical de la señal.
6. Seleccione una señal cuadrada (triangular) en el generador de funciones: visualizará así una curva cuadrada (triangular)en el osciloscopio.

• Encienda el generador de funciones de la derecha conectado al CANAL B (los dos generadores están ahora encendidos):

- Seleccione como ***tipo de señal*** la señal sinusoidal.
- Ajuste la ***frecuencia de la señal*** a un valor múltiplo entero (doble, triple,...) del elegido para el generador de la izquierda.
- Elija como ***amplitud de la señal*** un valor igual al del caso anterior.

- Como ***desfase de la señal*** vuelva a elegir el valor 0, de momento.
- El valor del ***offset de la señal*** el valor 0.

- En el osciloscopio:
- Seleccione el CANAL B.

- Escoja el ***modo DC*** o ***AC***.
- Ajuste el ***trigger*** con:

Slop +

SINC AC

CANAL B

- Ajuste la base de tiempos para observar adecuadamente la señal en la pantalla.
- Ajuste la escala de amplitud para observar adecuadamente la señal en la pantalla.
- Mida la amplitud y frecuencia de esta señal en el osciloscopio.

- Seleccione el modo DUAL: veremos las señales captadas por los dos canales de manera simultánea en la pantalla.

Ambas señales permanecerán fijas en la pantalla ya que sus frecuencias son múltiplo la una de la otra y el disparo está sincronizado con ambas.

Si cambiamos el ***trigger*** al CANAL A todo sigue igual.

- Cambie la frecuencia de una de las dos señales proporcionadas por sendos generadores de funciones:

♦Observará que la señal del CANAL B (que ahora no dispara el ***trigger***) se mueve en la pantalla.

♦Si cambia el ***trigger*** al CANAL B, la señal del CANAL A se moverá en la pantalla.

- Determinemos el desfase entre ambas señales:

♦ Ahora mismo se encuentran en fase. Para que no lo estén, introducimos a la señal generada por el generador de la derecha por ejemplo, un desfase arbitrario (90º).

♦ Mediante el osciloscopio haciendo uso de los botones para mover la imagen hacia derecha/izquierda y arriba/abajo podemos medir el desfase entre ambas señales.

♦ Dejar igual la frecuencia del generador 1 y varíe ligeramente la frecuencia del canal 2 (ej: 100 y 110), pulse en el osciloscopio el modo suma, modifique el control de escala horizontal, ¿Que se observa en la pantalla del osciloscopio ?. A la señal obtenida se le llama de amplitud modulada.

♦Pulsando el ***modo XY*** del osciloscopio y haciendo uso de las figuras de Lissajous también puede medirse dicho desfase

- Finalmente observe qué le ocurre a la señal observada en el osciloscopio al pulsar un botón cualquiera del mismo (p.e. **x5**, **Pull Invert**,...).

APENDIX II:

FIGURES

Figure 1: Initial Screen of the Tutorial

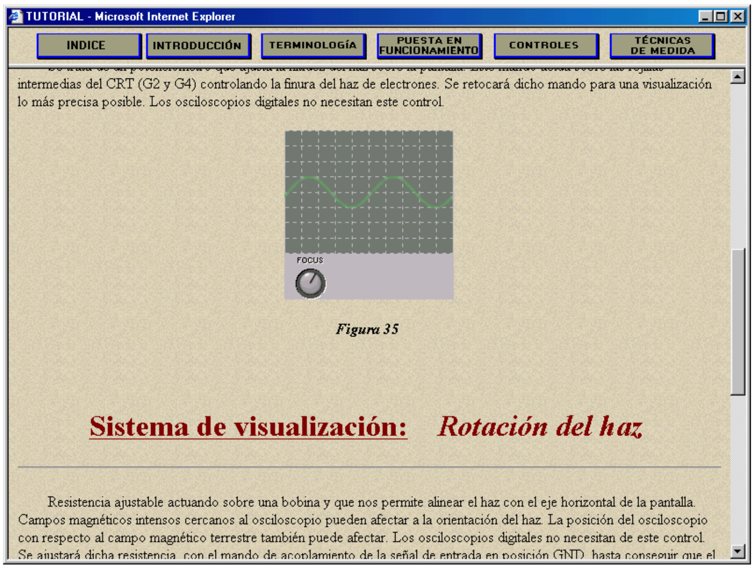

Figure 2: Oscilloscope controls Screen

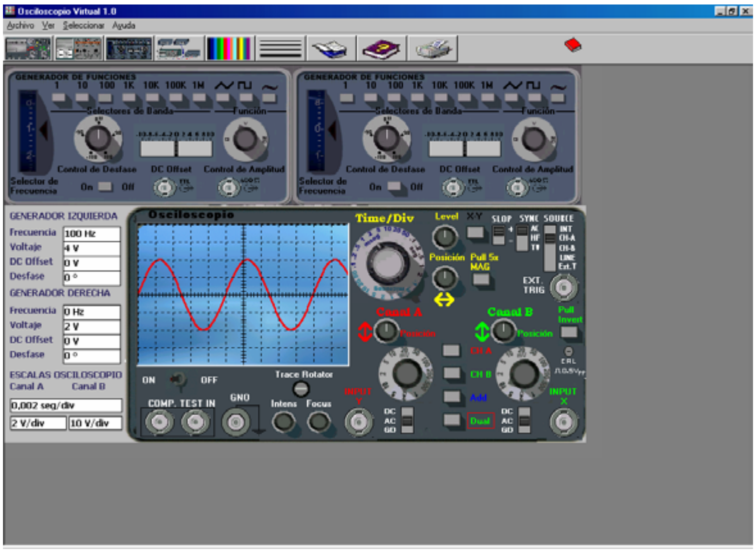

Figure 3: Analogic Oscilloscope

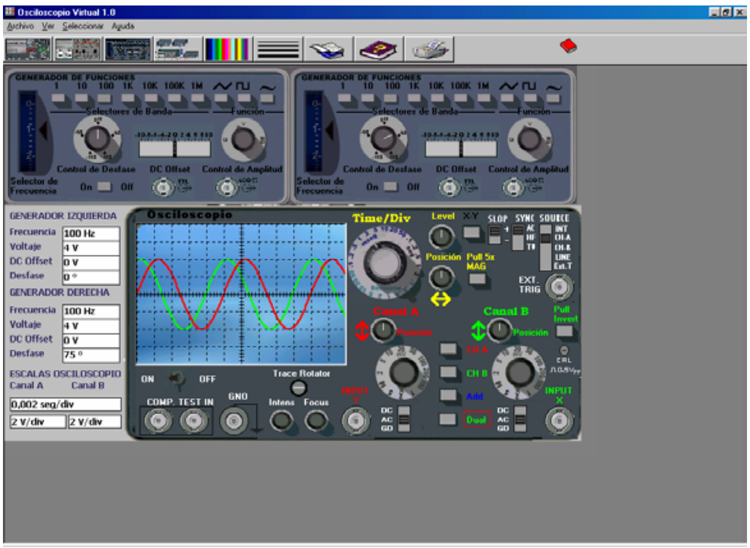

Figure 4: Disphase between two signals

Figure 5: Addition of two signals of similar frequencies

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