Application of simulation and interactive virtual laboratories in university teaching of physics and chemistry in a project for establishment of ECTS credits in the E.P.S. of the university of Córdoba

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This article is about the development and use in university teaching of Information Technology applications, whose objective is the implementation of Virtual Laboratories in which different Physics experiment problems can be resolved. These Programmes are characterized by the experiments approached being conducted step by step, following the same experiment procedure as in the laboratory and obtaining the corresponding numerical and graphic results. They include permanent assistance and tutorials, which are accessible from any part of the programme, as well as an evaluation module. With these applications, it is sought to make students develop their capacity for self-teaching, to prepare experiment practicals which they subsequently have to carry out in the laboratory and to revise as many times as necessary the experiment processes and results obtained. As a consequence, teaching quality can be improved with the use of a computer as a complementary learning tool.

Keywords Teletraining and Self-training; Simulation, Virtual laboratories; Technological education; ECTS.

1. Introduction

In the past twenty years, important changes have come about in the area of research related to the teaching of science, linking two different but complementary lines: on one hand, the formulation of new didactic intervention models oriented towards the construction of significant knowledge [1], and, on the other, the application of the new information technologies (computers, audiovisual media, multimedia equipment), which are exerting an increasing influence on education through the creation of new didactic material, which permit students to carry on a type of learning of an interactive nature [2] [3].

Many studies [4] have demonstrated the usefulness of the new technologies at an educational level. Within the field of scientific and technological education, we believe that the computer can be used as a study tool where students are the protagonists of their own learning process [5], [6], [7].

From this perspective, our line of work has focussed on the development and evaluation of computing applications,which include different modules: diagnosis of knowledge and previous ideas, the solving of problems, numerical simulations, virtual laboratories, interactive tutorials, etc. From an educational point of view we think that the main didactic usefulness of the tools proposed is that they offer simulations of scientific phenomena and virtual experiments can be conducted with a certain degree of realism so that the student can modify the independent variables or the initial conditions and analyze the changes produced in the systems [8].

The main advantages of this type of educational resource are: its ability to represent situations which in practice are irreproducible, the idealization of experiment conditions, the setting up of situations which normally require costly and complex equipment and of which few prototypes are available, the use of models showing partial aspects of reality, the handling of dangerous processes, the manipulation and control of variables, etc. But, above all, we believe that they can help to solve the problem of overcrowding in classrooms and laboratories at a low cost since use can be made of computer rooms in the

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training centres as an infrastructure support, much more versatile and cheaper than experiment laboratories, which are specific to each subject [9].

For all these reasons, we are working on the development, application and evaluation of virtual laboratories and their use with students, and have obtained a series of encouraging results already expounded in other papers [10], [11].

With the aim of bringing together all the computer applications developed and assisting students in their self-teaching process, a server web has been created: http://rabfis15.uco.es in which the different applications have been posted, both those which can be downloaded and later installed in a personal computer, and those which can be executed directly on-line. Similarly, other pages have been set aside for each teacher and subject, in which guides of the practicals, both simulation and experiment, themes, questions and problems are distributed to students.

These new instruments permit us, in addition, to improve the tutoring of students in the subjects in the first year of Principals of Physics at the Superior Polytechnic College, in which there is a poor student/teacher ratio (190 students/1 teacher). However, these computer tools would give better results if the student/teacher ratio were to improve and, therefore, the time devoted by the teacher to each student would be longer, better and more effective.

2. Implementation of the VLS in the general context of Principals of Physics subjects in Engineering

The development, in the Department of Applied Physics at the E.P.S., of computer applications with didactic aims, began during the academic year of 1988-89. In the year 1991-92 they began to be taught to students in the diploma course of Information Technology, in the form of experimental classes in the simulation of physics phenomena; a first article was published in the journal *Enseñanzas de las Ciencias* in 1994 [10], on the didactic results obtained and in which the computer technology application was described.

Since that academic year of 1991-1992, the teaching of simulation practicals together with experiment practicals has been generalized in the Dept. of Applied Physics in the EPS for all students in the first year of different Engineering subject studies.

In the general context of the subject, four practicals are conducted in the Computing Centre under the direction of the teachers of practicals. Of the remaining experimental classes, in two of them, Sound and Geometric Optics, students have to perform, previously and autonomously, the corresponding simulation practicals. It is thus intended for them to learn how to do the work, predict the results and compare them by means of a simulation with the experiment practicals.

The computer applications developed are being used with students of different degree and diploma courses at the Superior Polytechnic College, E.P.S. University of Córdoba. The action sphere of this experiment comprises six subjects involving three degree courses. The total of students at present participating is somewhat over 600 students.

3. Objetives

To develop this line of work we set a series of objectives among which can be highlighted:

* To broaden the field of teletraining and to expedite the establishment of practicals simulated by computer, using as a support both software already developed in our department and new software projects which could be executed directly without needing to be installed in personal computers.

* To create a single web site comprising all the simulation works in the field of Sciences and Technology, as well as the virtual laboratories developed by the team and the new ones which have been set up in the latest stage, together with the incorporation of a single evaluation system (evaluation agent), an examination administrator and the web for the creation of interactive laboratories.

4. Description of the web and of the virtual laboratories

The web page begins with the presentation screen shown in Figure 1. As can be seen, at the top there is a series of options which access to the different sections included, such as Introduction, Objectives, Antecedents, etc. In Software Download the user enters, by means of a password, the installation programmes of the different virtual laboratories. In the online area section, the student can consult the tutorials configured in HTML and use them as theoretical documentation. He/she can also opt to enter directly into the different multiplatform virtual laboratories: for instance, Electrostatics, Sound, Optics, Single Pendulum, etc, and work with them via Internet (Figure 2).

Fig. 1 Online area of software (VL)

Fig. 2 Virtual laboratory on sound

The web created also has pages associated with teachers and subjects from which students have access to all the complementary material of the subject, as well as the guides of the experiment and simulation practicals.

4.1. Description of a teaching experiment: carrying out an electrostatic fields and potentials practical

The application, *Electros 2.0,* is integrated by the following sections accessed to from the opening screen: *Tutorial, Simulation, Help, Evaluation test and question manager*. The latter is a tool for the teacher with the purpose of enabling him/her to create and manage evaluation tests.

The simulation section is of the greatest interest in the solving of electrostatics problems and for that reason we shall now describe it.

Simulation: This is the section in which a study is conducted, by means of simulation, of electrostatics fields and potentials due to different elements which can either be studied independently or freely associated.

The work display screen which is freely scaled and to which the elements are dragged, by clicking the mouse from the taskbar located on the left vertical area. When placing the element on the work board, a window opens in which the load value is assigned, as well as the position values.

The dielectric elements which can be studied are: specific loads, infinite wires, infinite planes, spheres and cylinders. Also in this elements bar is a test load which permits us to verify its movement when placing it in the sphere of the electrostatic system created.

At the top right-hand side there is a bar with different tasks like, for instance *file* (open, save, print, etc.), *parameters* permitting us to freely scale the work screen, *calculuses* (field values, potentials and forces), *graphics* (Force field lines, equipotentials, etc.), *elements*, which are the same as appear on the left-hand vertical bar, *tools* (notebook, calculator) and *helps* (programme help, tutorial and about…).

Under this bar there is another with fast access keys containing the main tasks found in the previous one.

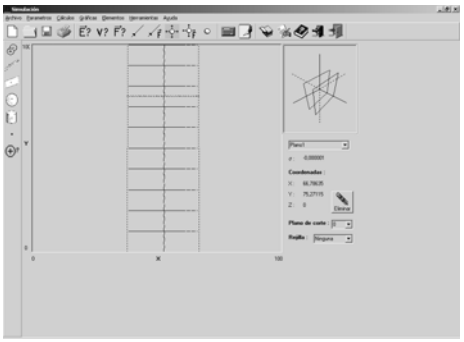

Fig. 3 Loaded parallel planes: + σ y - σ

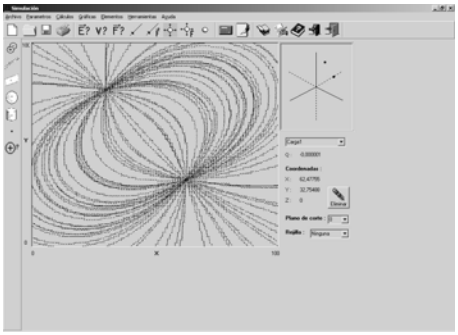

Fig. 4 Electric dipole

Figure 3 shows a system constituted by two equal-load parallel infinite planes, in an absolute value, but opposed (plane condenser). The lines of electrostatic fields, and the equipotential ones, can be seen in it. It can also be verified that there is, at the top right-hand side, a tridimensional *zoom* where the system is represented.

In Figure 4 an electric dipole has been designed and the field lines, force and equipotential surfaces have been studied.

The student has to carry out a practical following a programme guide and then hand in the results of this work, which are evaluated within the general context of the subject.

5. Results and didactic evaluation

In order to test the degree of influence of the virtual practicals on the learning process, the results of the practicals of the past five academic years were compared.

Of the 160 students enrolled in each academic year, approximately 100 of them registered in http://rabfis15.uco.es/deptfisica/eps/validarlistas. This was an indispensable condition for carrying out the practicals and, therefore, finally, for passing the subject, so that the remaining 60 students did not even begin the course.

Of the 100 students who began the course, about 90% did the real and virtual experiment practicals and, subsequently, handed in their reports. This was an essential condition for passing the subject of Principals of Physics in Information Technology.

The evaluation of the programmes used was done through the individual reports handed in by students on finishing the experiment and through supplementary questionnaires on the topics handled.

This evaluation was analyzed by making a classification of the results obtained by students and establishing three knowledge categories, as follows: Abandonment, Failures, Passes.

The results obtained showed us that in the past three years the number of students giving up the practicals, and hence the subject, has dropped. In addition, in the same period, in which the virtual practicals have been increased and coordinated, the percentage of failures has diminished and the frequency with which students have improved their results in the practicals has increased.

We have therefore come to the conclusion that the initiation and implementation of virtual practicals in co-ordination with experiment practicals have signified an increase in teaching improvement.

5. Conclusions

In this work, computer applications developed by our team for didactic purposes in the university teaching of science and technology have been presented. These are being used and evaluated at present – in real educational contexts – with first-year students in different Engineering modality studies.

These programmes are equipped with extensive tutorials, developed with hypertexts and images facilitating an understanding of the concepts. They include animations, sound and videos which increase their appeal to students. The latter can browse the different parts of the Tutorial by means of hyperlinks and buttons which connect to different parts of the system.

The simulations and virtual laboratories of real experiments are, undoubtedly, the most important aspect of these applications. In them, students can interact actively by introducing data into the independent variables, in the observation of the experiments, in the analysis of the results obtained and other aspects related to the solving of problems tackled.

So, we consider that these programmes are compact, intuitive, easy-to-use tools which coalesce in a single application the main elements intervening in the educational process: theoretical contents, practical activities (solving of problems, simulations and virtual experiments) and the evaluation of previous or acquired knowledge. Also, they possess an open instrument (the test manager) which can only be used by the teacher.

Through our teaching experience, we have been able to ascertain that these programmes help to improve the motivation and learning of the science subjects that we teach, and that they serve to incorporate students into the domain of computer sciences, as well as introducing technical and methodological innovations in university teaching, based on the new computer technologies.

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