

# SIMULATION ELECTROMAGNETIC WAVES WEB AS INNOVATIVE METHODOLOGY TO IMPROVE THE QUALITY OF ELECTRONIC AND COMPUTER ENGINEERING FORMATION

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**Abstract:** In this work an introduction to the main design features of a computer-aided educational package addressed to students of the final years of Electronic and Computer Engineering is presented. The Software includes interrelated tutorial, computer simulations and test questions, in which graphical outputs, hypertexts and animations are widely used. The package is devoted to the simulation study the concepts and propagation electromagnetic waves. It provides instant numerical evaluation and a graphical display of different studies. The software presented in this paper has all the following features: an integrative character, personalized and active learning process, adaptability to teacher's aims, versatility as a teaching tool, multimedia resources and simplicity. This study has been carried out with final-year students at the Superior Polytechnic School of Cordoba (Spain), with highly favourable results when compared with students who did not use the software.

## 1 INTRODUCTION

At present, the main objective of many software systems developed is teaching and the transmission of knowledge. The use of a computer for this purpose accelerates the learning process of the notions provided by the system since interacting with it helps the contents to be assimilated more quickly and placidly (Martínez-Jiménez, P., Varo, M.; García, M. C.; Pedrós Pérez, G.; Martínez-Jiménez, J. M.; R. Posadillo, R.; Varo-Martínez, E.P, 2009).

Some published works show the interesting possibilities offered by computer applications to promote the comprehension of concepts by means of the conceptual change process. Both solving problems and the approximation and performing of

experiments by pupils can be considered guided activities (Ras E., Carbon R., Decker B., and Rech J., 2007). Thus the computer can be used as a reflection device, in which students are the protagonists of their own learning process (Stefanovic M, Matijevic M, Cvijetkovic, 2009).

The creation of a virtual laboratory permits the dissemination of that information to its final users and the teaching of theoretical-practical concepts by experimentation making use of the new technologies (Romero, C.; Ventura, S.; De Bra, P., 2009). In addition, the expansion of the software through Internet makes it easy for any professional or student interested in the theme developed to use the laboratory and benefit from its contents, thus obtaining a didactic complement to the traditional theory classes (Avouris, N.M. Tselios, N.; Tatakis,

E. C.; 2001).

In order to improve the rate of success and to adapt the curricula of electronic and computer engineers to the requirements of new societal and industrial challenges, a new discipline (subject) in higher education was introduced at the Superior Polytechnic School of Cordoba University, Cordoba, Spain: “*Optical Communication Systems*”.

The course on *Optical Communication Systems* has a total of 45 hours assigned. The main topics treated are:

1. Electromagnetic waves
2. Optic
3. Electro-optic theory and devices
4. Acousto-optic theory and devices
5. Optic fiber
6. Optic Communication Systems

In the normal course of the subject, throughout the first and second academic years (2004/2005 and 2006/2007), the teachers in charge noticed that students had difficulties in understanding electromagnetic waves thematic units. In order to improve the level of teaching and encourage self-learning, it was decided to develop a computer application (Simulation Laboratory), which would enable students to study all the basic theoretical aspects of these disciplines and permit the simulation and visualization of general problems, obtaining both numerical and graphic results.

For that reason, the research team carried out an educational project related to the development, application and evaluation of an Electromagnetic waves Multimedia Web Simulation Laboratory (<http://rabfis15.uco.es/espectroscopia/>) (OEMSL), in which a theoretical-practical study was conducted into basic principles and propagation of electromagnetic waves.

The general aims intended in this process were:

- to relate the theoretical and practical aspects of teaching.
- to ensure that students obtain sufficient information on the nature and propagation of electromagnetic waves.
- to improve the self-learning process and induce a critical analysis of the results.
- to provide an active and more personalized education to motivate the student.

To achieve these ends, the research team has taken into consideration the results from the evaluation of work in previous years. The educational experiment was carried out with the final year of Electrical and Computer Engineering students and for two consecutive years.

In this work the design process of a first program, together with a summary of the results obtained in its experimentation will be presented.

## 2 DESCRIPTION OF SOFTWARE

The software used in the experiment was developed in a Windows environment, using a multimedia web programming tool (Microsoft .NET).

The virtual laboratory is on-line in the Applied Physics Department of the University of Cordoba web page in Internet (<http://rabfis15.uco.es/espectroscopia/>) and it is a free access program.

The application consists of three different parts, but connected to each other: Tutorial, Simulation, and Help.

### Tutorial Module

In this module, different concepts, basic principles and properties of electromagnetic waves, related with the topics dealt in the OEMSL are explained in illustrated and animated tutorials. Their objective is to expound, clearly and concisely, the principles ruling the mean concepts and properties, as well as the basic electromagnetic waves and spectroscopic theory, with a direct application of these effects.

### Help Module

The Help module consists of a series of documents in a HTML format, which explains the functioning of each of the sections making up the program.

### Simulation Laboratory Module

This 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. In this module there is a series of options corresponding to each of the cases to be analyzed: electromagnetic waves, reflection, refraction, diffraction, interferences, spectroscopy etc. As a study sample the Laboratory corresponding to the interference of two coherent sources (Figure 1) is considered. In Figure 2 the screen corresponding to the spectroscopy study is also shown.

These simulation screens have been designed to include horizontal buttons. In the horizontal quick-access buttons, there is a direct access a simulation and representation of phenomena study.

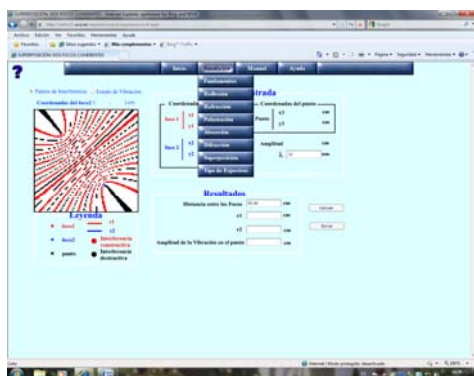


Figure 1: The Interference of two coherent sources. Stationary interference pattern.

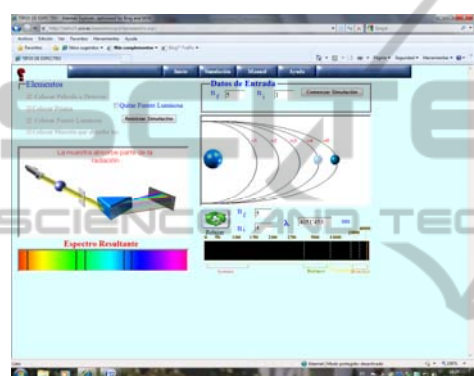


Figure 2: Spectroscopy Study.

### 3 WORK METHODOLOGY WITH OEMSL

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, a program-guide of activities is designed, which direct the students' interaction work with the computer.

This program-guide can be presented as an additional document that is available in the web <http://rabfis15.uco.es/deptfisica/eps/> and also <http://www3.uco.es/moodle/>.

The overall activity, made up of a large set of specific tasks, consists of accessing to the simulation module and performing virtually some simulations such as the case of the study of the waves, and different phenomena, following the steps proposed by the program guide.

Finally, students are asked to meditate on the results obtained 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 overall activity of the program-guide, in which students are invited to reflect on and analyze what they are observing in the simulation

## 4 DEVELOPMENT AND EVALUATION OF EDUCATIONAL EXPERIMENT

### A. Experimental Design of the Research Work

As well as developing didactic software, it is 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, as it has been done with the pupil "Optic Communications Systems".

With the aim of checking the degree of reliability of the tool used and its influence on the lecturing improvement of these subjects, four groups of the total of students were set up. Two of these groups following a traditional teaching method {control groups GC1 (n=14) and GC2 (n=16)}, based on a theoretical exposition and Classroom practice. The other two groups had been given the same theoretical-practical contents using the OEMSL as a complementary tool in the learning process {experiment groups GE1 (n=15) and GE2 (n=15)}

The lecturer team has therefore proposed one main research objective: to contrast the results in training acquired by students in their knowledge of the basis and devices when working with the simulation laboratory, and when they only received traditional teaching.

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

1. To learn about the physical basics of the electromagnetic waves.
2. To acquire the necessary knowledge to determine the basics of the different phenomena.
3. To relate the theoretical-practical aspects in order to be able to solve practical problems.

### B. Description of the Process followed in the Experimental Stages

The following is the process followed:

*1st Lecture Section: Common to the four groups, in which the fundamental concepts are explained.* Students have previous written information on them.

*2nd Classroom practice:* Here the problems proposed and later solved by students are commented and discussed, the class being given to each group individually. The control groups have two hours per week.

The experiment groups have 1 hour weekly of problems and 2 hours every two weeks of laboratory simulation. On average, they receive the same number on hours, the difference is that the experimental groups solve the problems with the simulation software and the control groups don't use the virtual program. The students are provided with a program-guide, in which the process to follow is indicated, as well as the problems to be solved through a Simulation. All the questions they may have are resolved by the lecturer giving the simulation laboratory practice.

The students in the control groups are given the same practical cases as the experiment group ones, and they can solve them in small groups in the practice class under the supervision of the lecturer in charge of it.

After working with the software, the students from the experiment groups did the same practice works as the control group students. On finalizing this process, each student gives 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 proposed problems.

To carry out the study made with the control and experimental groups, a set of questions and exercises that students must resolve individually completes the instruction. These exercises are practical problems that require the revision of prior theoretical information.

The time devoted to the study of these themes was similar in all the groups since the experiment group students substituted 1 hour of Classroom practice for the Laboratory Simulation. The experiment groups had the advantage of, when carrying out the practice exercise, being able to consult at any moment any question they had on the theory since, in each simulation screen, there was a link to the theme in the tutorial related to that specific simulation. 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 to the Tutorial questionnaire.

### C. Evaluation of the experiment

In order to make an evaluation of the development of this educational experiment, i.e., to study 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) The quality of the work reports drafted by students at the end of the virtual laboratories (Experiment Groups) and the work presented by control group students concerning the practical cases resolved in the practice classes (between 0 and 10 points).
- b) The results of a set of questions and exercises that students had to resolve individually (between 0 and 10 points).
- c) The results of a written test made up of several questions, in which students had to demonstrate that they can relate the theoretical-practical aspects involved in the study (between 0 and 10 points: 1 point/1 true question, 0 point/ no answered question and (-1)/ wrong question ).
- d) The results of an exam in which a practical problem was proposed (between 0 and 10 points).

## 5 ANALISYS OF RESULTS

For the study of the evaluation results for each of the objectives, the partial marks assigned to the students in the different groups is taken 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: between 0-5 points), category II to average marks (fair or semi-acceptable learning: between 6-7 points), category III to high marks (good learning level: between 8-9 points) and category IV corresponded to very high marks (very good learning level between 9-10 points).

Figure 3 shows the results obtained by the students in the control groups GC1 and GC2, corresponding to the evaluation of the three objectives (1<sup>st</sup>, 2<sup>nd</sup>, and 3<sup>rd</sup>), allocated to categories (I, II, III and IV). The relative frequencies or percentages corresponding to each of the four levels established for each objective and group are shown in columns, those on the left being for group GC1 and on the right those for group GC2. It can be seen that the results obtained by both groups are fairly similar. On comparing the results from GC1 and GC2 in each of the three objectives, it was observed

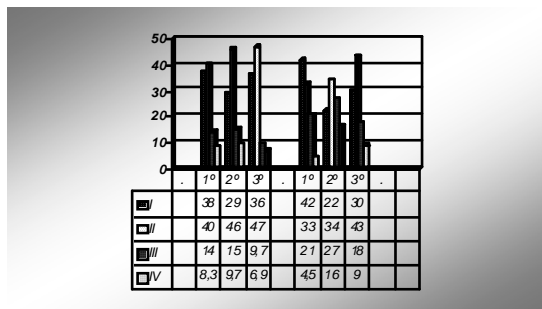


Figure 3: Results of learning objective evaluation in the control groups.

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 were noted. This means that both groups had developed a similar learning process and had reached a similar performance level.

In the experiment groups, the same evaluation process was followed as in the control groups. Figure 4 shows the results obtained by the students in these groups, on the left are the GE1 group data and on the right those of group GE2. This figure shows 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 were logical because both groups had the same initial characteristics, had carried out a similar study process and had reached a similar performance level.

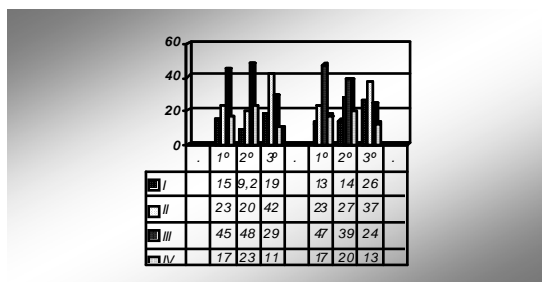


Figure 4: Results of learning objective evaluation in experiment groups.

In order to analyze 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.

For instance, on analyzing 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 the consideration of the use of the software described, had contributed to improving knowledge about the physical fundamentals in the experiment group of students.

With regard to the third objective, the comparative analysis shows that the result was also better in the experiment groups than in the control groups, so that it can be said that the use of software favored the development of the procedures and skills necessary for the resolution of the questions and the practical problems.

Finally, the research team 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 three 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<sub>I</sub> (overall mark between 0 and 10 or deficient learning capacity), L<sub>II</sub> (overall mark of between 10 and 20 or semi-acceptable learning capacity), L<sub>III</sub> (overall mark of between 20 and 30 representing a good level of learning) and L<sub>IV</sub> (overall mark of between 30 and 40, corresponding to an optimal or very good learning result).

Figure 5 shows 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<sub>I</sub> and L<sub>II</sub> show a higher percentage in the control groups with respect to the experiment groups. On the contrary, in level L<sub>III</sub>, the experiment groups obtained much better results than the control groups (with differences of over 20% between these groups). Finally, in level L<sub>IV</sub>, all the groups reach similar although low percentages which indicate that there were difficulties in achieving an optimal

performance level both for the control groups and the experiment groups.

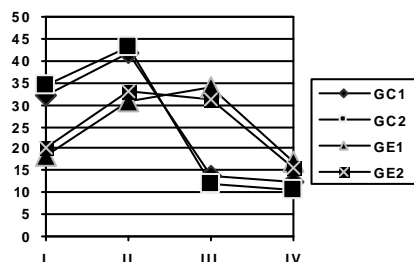


Figure 5: Comparative study of grade frequency versus the different marks for each of the groups participating in the study.

From a statistical processing of the overall marks of the four groups (with a Kruskal-Wallis test), it can be deduced that the use of the Simulation Laboratory favors 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, 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 higher level of specific knowledge and a greater interest in the subject, regardless of the teaching methodology.

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. These facts would appear to confirm the results obtained in other studies showing the favorable influence of the use of simulation programs in the teaching of physics and of other sciences (Lee WJ, Gu JC, Li RJ, et al. 2002; Becerra VM, 2004).

## 6 CONCLUSIONS

In this article, an empirical educational piece of research has been described, from which it has been deduced that the use of an Electromagnetic waves simulation program can be used by students for a better comprehension of the main concepts used in the work of this subject, and can especially contribute to improve the work of those students who have the greatest learning deficiencies.

The software described is compact, intuitive and friendly and constitutes an effective new tool for introducing students to Electromagnetic waves

Science.

Indeed, after carrying out the study described here, the teachers have had the satisfaction of observing the tallying of the results obtained with other results from previous investigations, in which it was demonstrated that the use of suitable educational software helped to improve the learning achievements of students.

The use of this Simulation Laboratory as a learning aid which complements the traditional method has the following advantages:

- It permits the reflective self-training of students through their individual work, either as a clarification and complement to experiment laboratories or as a practical task.

- It permits teachers to focus on the explanation of the basic theories and reduces the time that at present is devoted to introducing the mode of operation and working.

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