

AN EXPERIENCE OF USING B-LEARNING TECHNOLOGIES TO TEACHING OPTICAL COMMUNICATIONS TO ENGINEERING STUDENTS.

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Abstract

This paper deals with a pedagogical experience carried out with under-graduated students at the E.U.I.T. Telecomunicaciones in Madrid, while coursing a subject of Optical Communications (OC). In this experience several B-Learning methodologies as well as technological resources have been combined, in order to get surpassing some difficulties well identified faced by the students of this subject. To find a reliable teaching strategy, the proposed methodology have been introduced step by step along three academical courses, adding progressively new learning tools based on Information and Communication Technologies (ICT) [1,2]. The outcomes of the students assessments as well as the surveys carried out with them, have show a high improvement degree of the educative process in this specific subject of their curricula. New and more refined technologies based chiefly on remote laboratories will be tested along the next courses to overcome some issues not well surpassed yet.

Keywords - Information and Communication Technologies, educative innovation, virtual laboratories.

1 INTRODUCTION

Photonics technologies have become increasingly important in the last few years, and the demand of formation of skilled graduates is growing rapidly. These professionals must be competent in the design, development and installation of photonics (or optical communication) systems [3]. In view of the relevance of practical skills demanded to communications engineers, several specific laboratory courses have been added into their undergraduate curricula to help students to gain those capabilities. This is the case happened at the E.U.I.T. Telecomunicaciones in Madrid, where the subject of "Optical Communications" has gone growing in practical contents with the addition of more laboratory experiments besides of offering to students a rich panoply of pedagogical resources adapted specifically to this subject. This paper is intended to show the experience carried out in this field in our institution during the last few years and so demonstrate the necessity of a model change in the way the Optical Communications subject is traditionally focused. The rest of the paper is organized as follows: the considerations about the specific issues found while teaching the subject of optical communications is presented in Section 2. The implementation of a special Virtual Laboratory and other multimedia material to support self-learning is described in Section 3, next follows a discussion over the self-assessment tool provided in Section 4. The point of view of the students is presented in Section 5. Finally, the paper ends with a discussion on new developments and conclusions in Section 6.

2 MOTIVATION

To understand the necessity to change the paradigm of teaching optical communications from the traditional passive "face-to-face" (f2f) way to a more effective strategy, it is necessary to highlight some of the difficulties faced by the students and professors while working into this subject. These issues have been identified thanks to the experience gained during more than twenty years of teaching this subject to many generations of under-graduated students. It is true that not all the generations of students have exactly the same difficulties in tackling the subject, but some structural

problems are repeated again and again. We can classify these teaching / learning problems (or educative challengers to the teachers) into three qualitatively meaningful categories:

2.1 Interdisciplinary nature

The study of optical communications subject at the university level entails a solid background knowledge of many technological and scientific topics in the more diverse fields, ranging from solid-state technology, quantum mechanics, electromagnetism, optics, etc., to coding theory, communication systems, basic electronic, and many more disciplines. As one can realistically suppose, it is almost impossible to expect the students holds a good formation degree in this wide knowledge repertory. This sometimes leads to serious disincentives or frustrations in the students towards the subject, and therefore to lower academic outcomes. At all times the professor must to find a delicate balance between scientific rigor and amenity in his/her explanations, while simultaneously trying to fill up the main "formative gaps" detected in the students. Fortunately at present, additionally to traditional written resources (books, class-notes, etc) used to learn any subject, the student can get more specific information about any topic of his/her interest through new information ways, mainly based on ICT resources. It is reasonable to assume that a problem distributed among several heterogeneous disciplines will be only satisfactorily solved with the aid of the most appropriate pedagogical resource in each case. Our policy is to provide to the students with a vast range of pedagogical solutions, in such a way that anyone can found the best tool to solve his/her specific doubts.

2.2 Concepts visualization difficulties

Another critical feature in the successful development of a course in OC is related to the difficulties shown by students to "visualize" some central concepts that appear in the development of this subject. In fact anyone who has taught a course in this area will know the serious difficulty to show the students the pathway followed by the skew rays propagating down an optical Fiber, especially in graded-index fibers. Of course this, and many more examples, demonstrates to us that to teach some topics, the best way is not the mere employ of the chalk and the blackboard, even a good drawing on acetate and an overhead projector could not be enough expressive. It is necessary to use more rich content and sophisticated resources, such as 2D and 3D animations with the possibility of changing the point of view of the propagating ray, make zoom, pause or replay the ray trajectory, etc. Indeed this is not a fanciful example, on the contrary, over the development of an OC course we can find many more: interaction radiation-matter, amplification process in an Erbium Doped Fiber Amplifier (EDFA), generation of the different noise sources in a photodetector, the optical pulse broadening in an optical Fiber due to several dispersion sources, the operating principle of an optical fusion splicer, and so many well know examples more.

2.3 Expensive laboratory resources

The last but no less decisive factor to considerer in forming the engineering graduate is the practical component of the curriculum. There is a strong and universal consensus in the academic community that a good practical formation has a major impact on shaping the students integral capabilities. Well-designed laboratories and projects not only guide learners to a better understanding of abstract theoretical ideas, but also construct their practical skills and improve the ability to analyze and solve new problems [4]. Additionally, at present, the ability to excel in laboratories is also critical to enter the engineering technology profession. There are, however, a number of problems that sometimes deter many educative institutions from setting up experimental courses in some disciplines, in particular in the field of photonics or/and optical communications. These problems usually include:

- Cost of equipment
- Safety aspects

2.3.1 Laboratory equipment budget

The introduction of an experimental course in photonics is inherently expensive. Almost all the components (optical sources, fibre patch cords, splitters, couplers, fiber strippers, lenses, etc), instrumentation (optical spectrum analysers, optical reflectometers, optical tables, etc) and systems employed to set up laboratory experiments in OC require state-of-the-art technology, involving a financial outlay far greater than is necessary when working in a lower frequency range. Let us think, as an illustrative example, in a simple laboratory exercise consisting of the measurement of the spectrum of a He-Ne laser, then to carry out this experiment a laser source, an optical spectrum analyser (OSA), a stable power supply, an optical table, an optical Fiber and a set of additional optical components will be required. The cost to set up this conventional experiment will be several thousands of euros and therefore it is a good reason to discourage any academic institution to fund this type of laboratories. Therefore a major dilemma arises: Is it worthwhile to promote academic laboratories of photonics in spite of the enormous associated cost?. Later in this paper we will return to this question trying to find an answer and some alternative and cheaper options will be more deeply discussed.

2.3.2 Safety considerations

Under this heading two different aspects of security will be distinguished. The first is concerning with the own components and equipment employed, and the second, and more important, refers to the health safety of both laboratory users: students and professors. Regarding the first safety aspect, it is important to remember that optical Fibers are mechanically fragile by nature (manufacturing material and thickness) therefore a careful manipulation it is necessary when working with them. On the other hand the rest of components used are either fragile (mirrors, lenses, positioners, etc) or static sensitive (laser diodes, photodetectors, chips, etc) or both simultaneously, and this easily damaged.

As concerning the second safety consideration (the human one) it is pertinent to recall that optical communications systems operate in the near infra-red region of spectrum, due to the low attenuation showed in this region by optical Fibers, and so all the components and equipment are designed to operate in this wavelength region. The invisible beam emerging from lasers or optical Fibers operating in the near infra-red spectrum (even emitting power levels of a few milliwatts) may enter the eye -and cause dangerous damage- without the user being aware that he /she is in any danger. Therefore to manipulate these devices or systems, some safety precautions must be always adopted. This is a difficult issue in regard to inexperienced users such as students and the educative institutions wishing to run experimental photonics courses will have to instigate comprehensive safety measures.

3 A SOFTWARE TOOL TO SUPPORT SELF-LEARNING IN OPTICAL COMMUNICATIONS

As exposed in the previous paragraphs the problem of teaching OC in higher education level entails the need to embrace new methodologies in order to surpass inherent issues of this subject. There is not, of course, a magic recipe that annuls all the enumerated problems, but partial solutions adequately guided that they make easier the learning work of the pupils in each topic. In the current Information Age framework the proposed approach is embedded in a Virtual Learning Environment (VLE) [5] and is materialized in the shape of two differentiated solutions:

- A Matlab[®]-based extended virtual laboratory
- A Multimedia book

In the following we will present in more detail each one of these innovative tools.

3.1 MATLAB Extended Virtual Laboratory

The employment of the powerful mathematical software package Matlab (and associated toolboxes) broadly diffused around the university community, to develop Virtual Laboratories (V-Lab) is not new, and there is a extensive literature on Matlab applications in the most heterogeneous scientific and technological fields [6-8] even in the topic of photonics [9,10]. On the market there are another similar mathematical software packages such as Mathcad, Maple or Mathematica, but we have selected Matlab because of his powerful function libraries, "open" structure of the programming environment and the capabilities to develop friendly graphical user interfaces (GUI) with rich and attractive graphic content [11]. In this way a truly interactive OC course have been implemented which combines the philosophies of both a "Virtual Teacher" (V-Tch) and a "Virtual Laboratory" in the same application, this juxtaposition of both features is what we could define as "Extended Virtual Laboratory" (EVL) Note that the purpose of both tools is slightly different:

- Virtual Teacher

With this program capability , the student interacts with the software in almost the same fashion as he/she would do with an "electronic book" or with an "electronic teacher". Namely the student can learn new theoretical concepts with an attractive visual support. But there is a meaningful difference: this content is not merely "fixed" and "static" as it would happen when reading a printed book, but on the contrary, the student can access to animated and interactive illustrations (by means of embedded Java applets) or even "to jump" to external references or sources thru e-links. A screenshot of the "first page" of both the V-Tch and the V-Lab (devoted to the "chapter" of Fiber Optic Propagation) as currently available is reported in Fig. 1.



Fig. 1 – Screenshot of the first-page after accessing the Fiber Optic Propagation module

On this "chapter" selected as an example, we can see the possibility to study the theory of dielectric planar waveguides (Slab) or to enter in the sub-menu corresponding to fiber optics, simply "pressing" the selected button with the mouse. New windows shall be immediately open after select either of the options, in order to develop the preferred topic or to practice with the virtual laboratory experiments included. Although at the present time the application uses the Spanish language, we are preparing a version in English too. Suppose we want to know more detailed information about the principles on which the slab waveguides are founded, then after point out with the mouse over the grey box entitled "Introduccion a la propagacion en medios guiados GUIAS SLAB", and after pressing the mouse left button, we will arrive to the new menu shown in the Fig. 2.

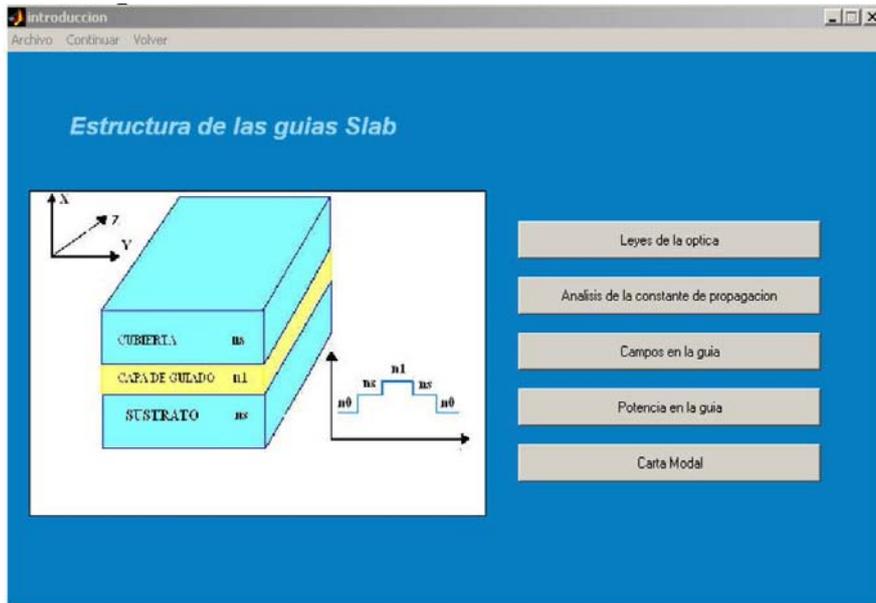


Fig.2 – Menu and sub-menus belonging to Slab waveguide chapter.

And now we wish to go further in the study of the power distribution among the various layers conforming the structure, then we must press over button entitled “Potencia en la guía” and we shall be brought to the “active” screen indicated on Fig. 3.

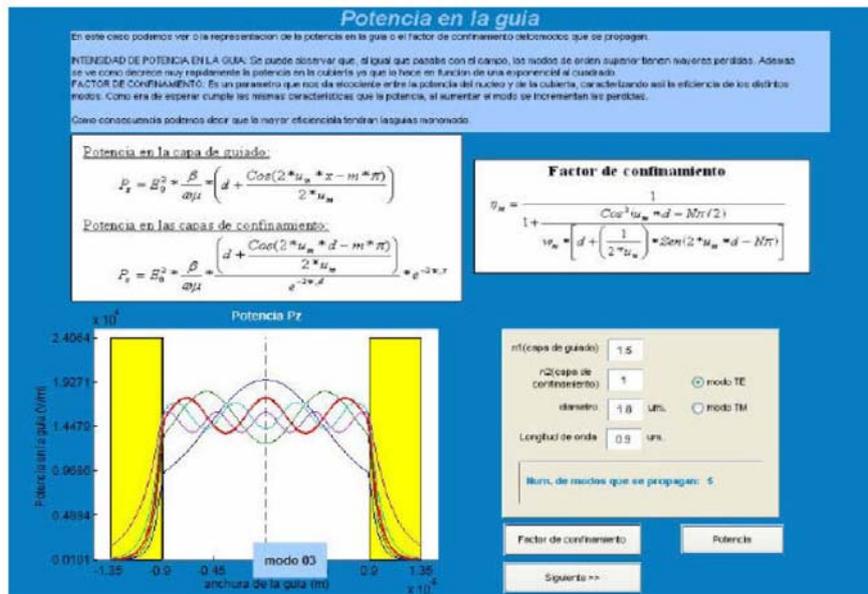


Fig. 3 – Screenshot of the page related with the power analysis within the Slab waveguide

It is noted that we have qualified this screen as “active” because the student in addition to have the corresponding (“passive”) brief theoretical explanation, he or she can interact with the “electronic book” changing various operative parameters and looking at (in this specific example) the new shape suffered by the optical power distribution. The operative philosophy so far described, with the aid of a particular example, for the “virtual teacher” holds up through the remainder of the theoretical lessons included. We are convinced this methodology contributes to reinforce the student engagement degree with those more cumbersome issues. It is obvious that in no way this application is conceived to replace neither the real teachers nor printed books; on the contrary, it is only an *additional* or *complementary* learning tool given to the student in order to increase his / her active participation degree on the learning process.

- Virtual Laboratory

Let us consider now the second available functionality in the extended virtual laboratory. This tool is fully integrated in the same environment as the “virtual teacher” keeping the same graphic aesthetic, but now the conceptual purpose is not the same. In fact the emphasis is being placed now in the experimental facet of the learning process. It is convenient to clarify, from the beginning, that our V-Lab belongs to the category of "Software Labs" (S-Lab) [12]. Therefore, at no time, there is an interaction with real devices or instrumentation, as would be the case of "Remote Labs". In this manner the student can play with the virtual experiments in a fully safe way. Even more, there is another additional advantage of using an S-Lab instead of set-up a real experiment: it is feasible to virtually *observe the internal operation* of both passive and active devices very easily, e.g. the carrier and photon population densities into a laser diode or the pathway followed by different rays propagating down an Optical Fiber, to put only two examples. Such characteristics whilst often extremely (or impossible) to measure experimentally have a great bearing on the comprehension of the device operation. Another illustrative example of the S-Lab capabilities is reported in Fig. 4 , which presents several screenshots of the radiation intensity profile of the four lowest modes propagating into the core of the Optical Fiber. These pictures are obviously simulated, but they fits well with the experimental results who could be obtained in a real lab employing the appropriate set up. The advantages here of using the S-Lab are obvious: any expensive instrumentation or special safety precautions are unnecessary.

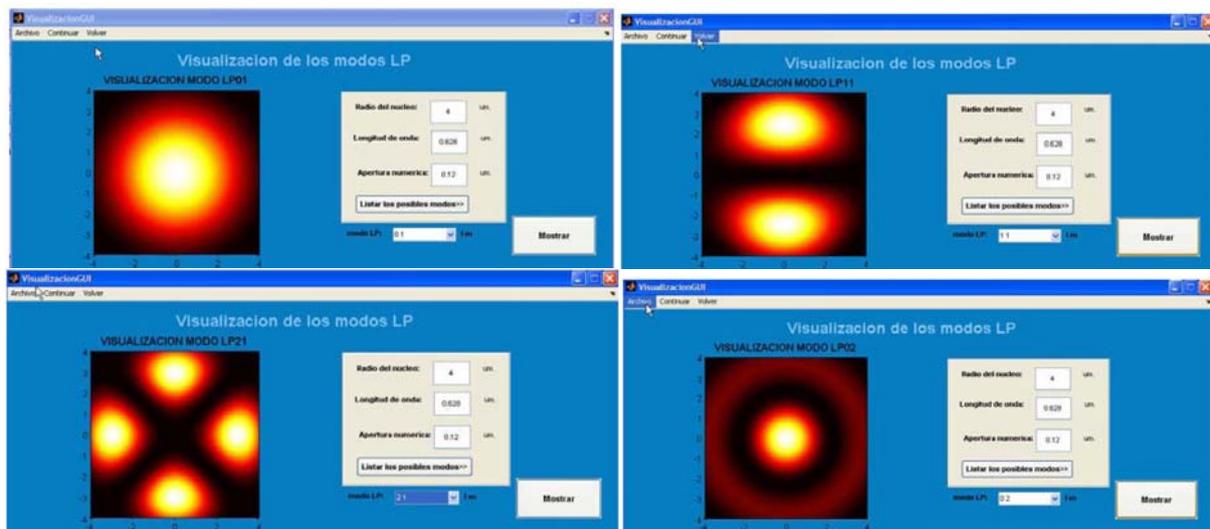


Fig. 4 - Simulated observations of the four lowest modes propagating down a optical Fiber.

In order to broaden the ways the student can access the developed application just discussed, we have distributed it in two different versions:

- As a set of interrelated separate files
- As a unique executable file

The first option runs more quickly but it is mandatory to have a licensed Matlab version installed locally on the PC from which the program is executed. On the contrary it is not necessary to have any Matlab version to work out with the executable version, but usually it goes slower. Both versions are included in a DVD given to the students coursing the subject of Optical Communications. This DVD contains some additional useful material to follow the subject:

- The Multimedia Book (that it will be described straightaway)
- Some *free* books in pdf format
- Some tutorial papers

Additionally a solution to execute the program in a remote way (anytime and anywhere) is also provided, by means of a on-line connection via Internet , linking the student PC with the host local server available at the university.

3.2 Multimedia book

Throughout the previous paragraphs the Matlab GUI have been described trying to highlight his usefulness as an intelligent professor, endowed of the necessary mathematical capacity as to teach the student, with *quantitative accuracy*, both theoretical concepts and / or practical lab (simulated) measurements so to completing a truly course in optical communications. This has been achieved through the extensive use of the Matlab mathematical capabilities and his powerfull graphical development environment. Nevertheless neither Matlab nor other similar standard mathematical packages are the best suited options to develop some multimedia material with both more ambitious audio and video content. This is the case when, for instance, the important objective is to underline the qualitative concepts needing sophisticated visual support instead of paid attention in the quantitative details, and therefore it is not necessary any mathematical apparatus. To fulfill this pedagogical challenge we have developed another specific software application [13], with a "modus operandis" resembling the Matlab EVL, but a quite different functionality. Actually, the audiovisual material elaborated is newly organized in a tree structure with up to seven chapters (at present) or "branches" emerging from a common trunk. The Fig. 5 illustrates the application main menu as presented in the english version. Of course, there is a spanish version including the same material available.



Fig 5 –Multimedia book - Main menu.

As you can see the imagen looks like the selection menu available in any movie DVD, and the seven chapters (equivalent to lessons) included are:

- The Light
- Structure and Classification [of the Optical Fibers]
- Dispersion in Optical Fibers
- Attenuation in Optical Fibers
- Light Emitting Diodes
- Laser Diodes
- Optical Fiber Manufacture

In each chapter we will find a interactive movie explaining with great detail a set of topics related with the chapter name. In turn each movie is formed with material of diverse nature, making use anytime of those more appropriate to best explain the issue analyzed:

- Free real movies from public and private institutions (with permission)
- Pictures and graphics
- 2D and 3D animations

As it happens with any conventional movie DVD, the user (i.e., the student) has to his / her disposal the standard controls to the DVD action: pause, stop, fast forward, etc . In this way the student has the possibility to assimilate the lesson content to his / her own pace. To appreciate what the student can find when browsing these videos, Fig. 6 illustrates a video frame captured from a 3D Studio Max© animation relative to Numerical Aperture concept explanation (on the left side), whilst on the right side a video frame of a real picture showing the optical Fiber fabrication process is presented.

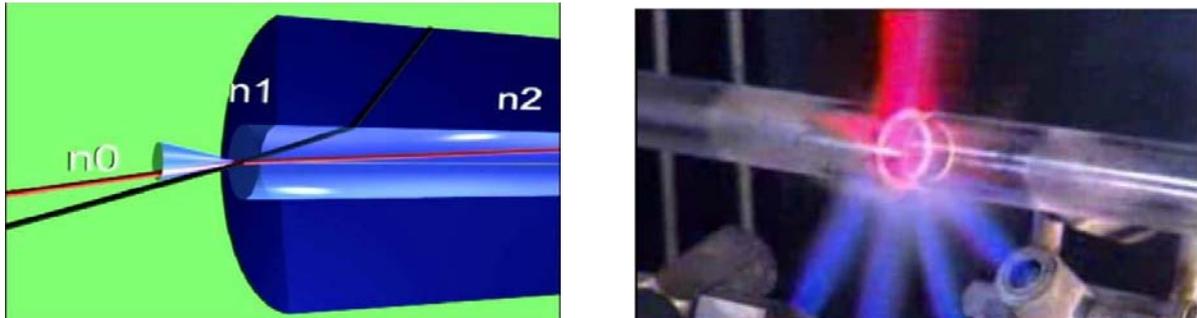


Fig 6 - Two samples of the DVD content: a 3D animation (left) and a real video (right).

As was stated at the beginning of the paper, our endeavor has been to put CIT technologies to the student service so to make profit of a truly b-learning environment. In this way we have also thought in the students who can not access to this DVD, by distance or any other reasons, therefore once more the Internet resource has been employed again to solve this handicap: all videos included in the DVD have been uploaded to the platform You Tube and can be easily localized by means of Google or any other search engine. There is, however, a loss in the on-line image quality. To put a simple example about what is offered, Fig. 7 correspond to two screenshots of the two-parts video explaining the attenuation mechanisms in a optical fiber.

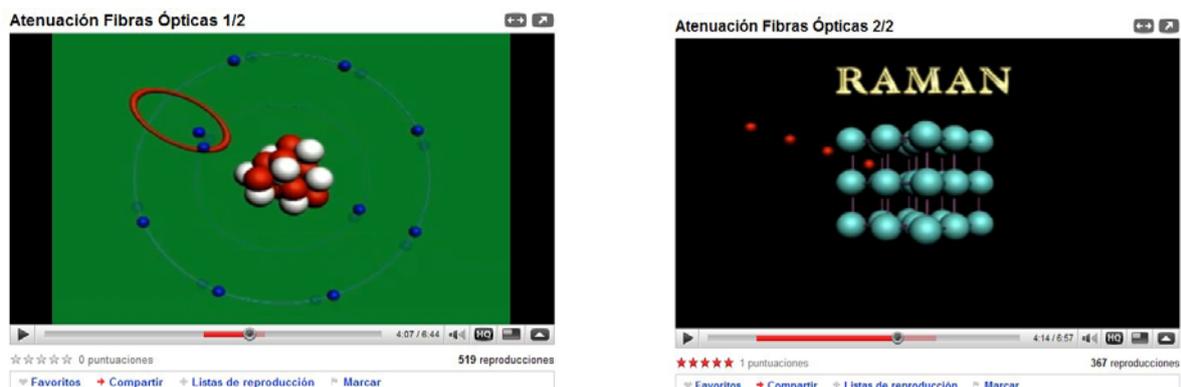


Fig. 7 – Two screenshots from the video devoted to optical fiber attenuation hosted in You Tube.

To see both full videos only it is necessary to click on the following e-links:

- Part 1/2: <http://www.youtube.com/watch?v=iC0N4rGGwnw>
- Part 2/2: <http://www.youtube.com/watch?v=1GhYkQ0HaY>

To complete the learning material provided in the multimedia DVD, a complete set of bibliographic references is also included. Moreover the student has a self-assessment tool to his / her disposal, and will be described below.

4 THE SELF-ASSESSMENT TOOL

Assessment is an integral part of learning process in higher education and can be considered *the* key driver for it. In fact, the assessment enables the certification of learning and can facilitate learning in its own right [14]. As it is well known, the pedagogues make distinction between two different types of assessment philosophies [5]:

- *Summative assessment*

This assessment is focused to grade and tell the students what they have achieved. It can be used to improve the learning process by providing feedback to the student, which can be used to highlight areas for further study and performance improvement.

- *Formative assessment*

This type of assessment is employed to promote the learning because it is designed to provide the instructor with rich feedback according to the assessment technique.

In an E-learning environment it is natural to introduce some type of Electronic Assessment System Tool (EAT) as the corresponding integrated tool. Since student is a key element in teaching (specially in a constructivist model), a well designed EAT would take into account the student answer, answer time and student feedback as parameters in his design. Rashad and others [5] has thoroughly analyzed the best strategy to implement a integrated assessment system within a student-centered model. The scope of our objectives was more limited in our approach (at least in the first version of the software application) and the EAT included in the DVD was conceived solely to help the student in two specific goals:

- To check by himself the level of understanding of the basic concepts developed in the multimedia material included in the DVD.
- To provide automatically the student some basic statistical information about the results and consequently offer some pedagogical guidance to improve the e-learning process.

We have designed the assessment tool to fulfill both objectives without the needs of the human teacher participation, so we shell denominate this methodology as *self-assessment*. The application generates, for each chapter of the multimedia book, a battery of questions with form of "Multiple Choice Questions (MCQ)" which are automatically (and randomly) selected from a predefined greater set. In this way the student can not know in advance what questions he or she will have to answer. In Fig. 8 an example of the kind of questions included is presented. In this case is referred to the "purpose of materials doping".

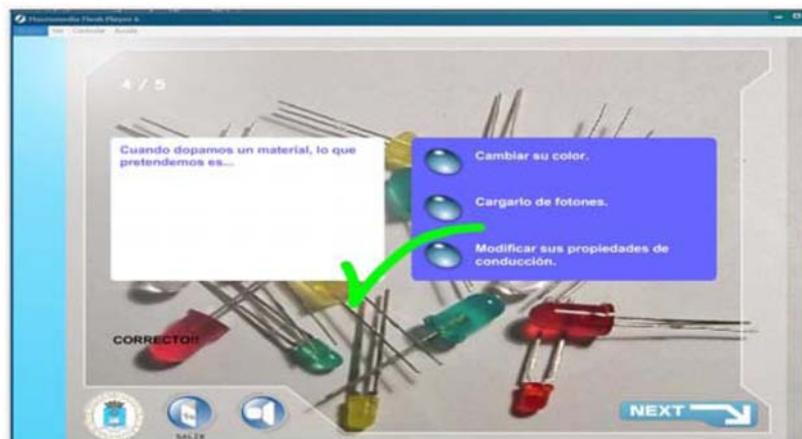


Fig. 8 – Screenshot of an example of proposed question to the student.

As was stated previously the application itself generates a brief report of the outcomes reached by the student after completing the test. Additionally also is presented an advice to help the student to identify his or her weak points, as in Fig. 9 is illustrated.



Fig. 9 – Outcome report and some advice to the student.

This application is programmed currently only in Spanish language, but the English version is also under preparation and will be included shortly.

5 STUDENTS OPINION SURVEY

Because the main objective of the material so far described is the improvement of the learning process, it is central to know how the students perceive these tools. Therefore following [15] a two-tier student opinion survey was performed. The first one was of free-form manner, where students wrote down their own free opinion and comments as they were browsing the diverse material put to their disposal. The second survey was conducted after their final examinations with the purpose to see how the students felt about the tools goodness in order to improve the knowledge of the subject. This poll procedure has been repeated during the last two years with a total of 27 students of the subject. A summary of the results of the opinion survey is shown in Table 1. In general, students value highly the quality of both the multimedia book as the Matlab application, but mostly prefer to be taught by a human teacher too.

Table 1 - Students Opinion Summary

	Strongly Disagree	Disagree	Agree	Strongly Agree
The Matlab tool improved my understanding of the subject	3%	17%	64%	16%
The Multimedia Book improved my understanding of the subject	5%	12%	45%	38%
In general the e-learning is a good complementary method to help the student	0%	7%	85%	8%
The e-teaching is better than face-to-face teaching	65%	33%	2%	0%
The Matlab virtual laboratory is helpful in making virtual experiments	6%	32%	53%	15%
The self-assessment tool is helpful to self-control the learning progress	14%	19%	50%	17%

6 CONCLUSIONS AND FUTURE WORKS

Two complementary software tools designed to assist undergraduates students in learning optical communications anywhere and anytime is presented. The first tool is conceived as a virtual (simulated) laboratory while the second one looks like a multimedia book with rich graphical content. The e-learning strategy has been offered (both in on-line and off-line versions) to students during the last two years, and they showed a high acceptance degree of the tools as a complementary methodology to traditional (face-to-face) teaching strategy. In order to update the e-learning approach new tools are being under development presently, including more virtual lab exercises, multimedia book chapters, the inclusion of some practices in a remote lab fashion and finally the integration of all over in a Learning Management System (LMS) environment.

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