A Project-Based Learning Approach to Teaching Power Electronics

Difficulties in the application of Project-Based Learning in a subject of Switching-Mode Power Supplies

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***Abstract*— This paper presents the introduction of Problem-Based learning (PBL) in a power electronics subject at the University of Oviedo (SPAIN) by means of two practical projects: the design and construction of a Switching-Mode Power Supply (SMPS) prototype and the static study of a dc-dc converter topology. The objective of this change in the traditional methodology of the Power Electronics course is to foster the application of the knowledge acquired by students in theory classes. PBL is known to be a motivating, problem-centered teaching method that brings the real professional world closer to the student. For this reason, the lecturers considered PBL to be the most suitable methodology to obtain the desired results. The underlying methodology, task planning and assessment of these projects will be presented. Furthermore, the influence of the introduction of PBL in practical sessions versus the traditional teaching method will be discussed. Finally, the lecturers' reflections and conclusions regarding the application of PBL in this subject over the last two years will be presented.**

Keywords- Proyect-Based Learning (PBL), significant knowledge, power electronics, switching mode power supply, practical sessions.

I. Introduction

It is well known that electrical engineers are recognized for their contributions to technology and for their improvements to global conditions. This is due to the fact that their main skill is the application of mathematics and scientific knowledge to the real world. However, traditional practical classes in Electrical Engineering curricula may obviate this fact because they are seen by students as a mere requirement without any interest in the real world. Therefore, the main skill involved in electrical engineering (the transfer of acquired scientific knowledge to society) is not enhanced because students do not see the real application of the work carried out in practical sessions.

On the other hand, the overall current aim of the Bologna Process is to create a European Higher Education Area (EHEA) based on international cooperation and academic exchange that is attractive to European students and staff from other parts of the world [1]. This means that all the undergraduate and masters degrees in Europe must have the same structure. In Spain, this change in the structure of university degrees is being employed to change the traditional methodology used to teach. Taskplanning and methods must now focus on student learning. Therefore, we must use active teaching methodologies to obtain significant student learning as opposed to mechanical learning. Significant learning goes beyond just understand-and-remember and even beyond application learning. In other words, students build their own knowledge on the foundations of their prior experience and know-how [2].

Taking into account the aforementioned motivations, a team of lecturers at the University of Oviedo (Spain) introduced the Project-Based Learning (PBL) methodology in a subject called "Sistemas Electrónicos de Alimentación" (Power Supply Systems) in the academic year 2007/2008. This subject, part of the final course of the Telecommunications Engineering degree, deals with Switching-Mode Power Supply (SMPS) and power supplies systems. The objective of this experience is to foster the application of the knowledge acquired by students in theory classes. In other words, the goal is to put into practice all the concepts regarding power electronics acquired during the entire course. For this reason, the lecturers proposed two projects to students: the design and construction of a SMPS prototype (boost converter) and the static study of a dc-dc converter topology.

First, this paper presents the methodology and task planning for the two projects. Second, the results of the application of PBL over the last two years will be discussed. Then, the lecturers in the subject present the main difficulties of the application of PBL after two years of experience. Finally, proposals aimed at improving the application of PBL for the current course and the conclusions will be presented.

II. Objectives of our experience. Why PBL?

Bearing in mind the main goal and the motivation underlying this experience, the lecturers in the subject gave them the form of more specific objectives. They were contextualized within the subject's requirements and were formulated as competencies which the student must have acquired by the end of the course:

1. To provide students with the fundamental concepts of SMPS and to prepare them for advanced study and research in this area: basic topologies, power supplies systems, passive components (inductor, transformer and capacitor), semiconductors, etc.
2. To learn how to search for, classify and analyze technical information about power electronics equipment and component datasheets and to be able to identify suitable sources of information about switching power supplies..
3. To provide laboratory experience to supplement theory in switching power supplies and to promote the application of theoretical concepts.
4. To provide students with the ability to propose solutions to problems and to enhance the critical reasoning needed to choose the appropriate solution in accordance with specific criteria.
5. To enhance other transversal competencies within the Telecommunications Engineering degree course such as the ability to write technical reports properly and to develop the ability to speak in public.

Having defined the objectives of the subject, the lecturing team had to select the most suitable methodology to obtain these goals. We chose PBL due to the fact that this methodology prompts students to encounter the core concepts and principles of a discipline while managing a specific task (project), thereby enabling the application of acquired knowledge [3,4]. Furthermore, PBL goes beyond the relationship between knowledge and thinking, helping students to both "know" and "do". In fact, this methodology focuses on "doing something" and "learning on the way". The main characteristics of PBL from the point of view of student learning can be summarized as follows:

1. PBL is student-centered and focuses on their main competencies. Students design the process for reaching a solution. Therefore, they focus the task around their main concerns and skills. In fact, the end product is a reflection of themselves. For this reason, students have no problem spending a lot of time implementing their projects.
2. PBL helps students to solve problems by themselves: self-management, project management and critical knowledge are enhanced. As they program their own work, PBL thus permits frequent feedback and consistent opportunities for students to learn from experience. Self-assessment takes place continuously during project development.
3. PBL recognizes the capacity of students to do important work and their need to be taken seriously by placing them at the core of the learning process. It engages and motivates bored or indifferent students. PBL is designed to establish a student's commitment to the task to be done.

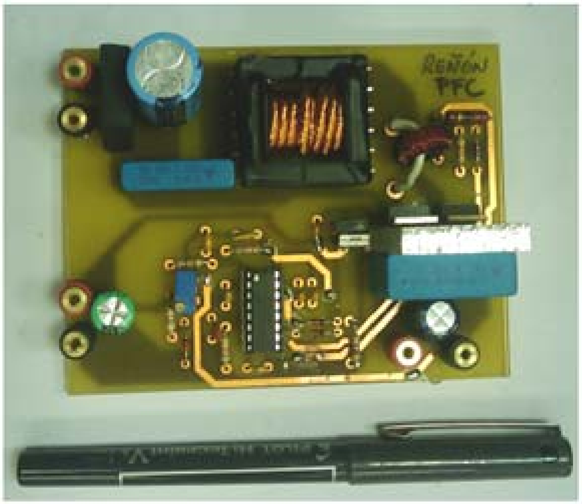

Figure 1. Switching-Mode Power Supply (SMPS) prototype made by a student.

4. PBL creates positive communication and collaborative relationships with lecturers and other students. PBL can help the lecturer to create a high-performing classroom in which the group (the lecturer plus the students) forms a powerful learning community focused on achievement, surpassing oneself and contributing to the community.
5. PBL includes the development of high-order knowledge and high-order competencies. Thus, PBL seeks significant learning.

Within a multidisciplinary educational context (i.e., Electrical Engineering, Telecommunication Engineering, etc.), PBL appears as one of the most interesting instructional strategies. In brief, the PBL strategy aims to engage students in authentic real-world tasks and open-ended projects that can increase motivation for most of them. For this reason, in recent years some authors have used PBL in their Electrical Engineering degree classes [5-7], in particular in their practical sessions [8-9].

III. METHODOLOGY APPLIED IN PRACTICAL AND PROBLEM-SOLVING SESSIONS

Two projects were introduced in the practical and problem-solving sessions of a SMPS subject forming part of the University of Oviedo Telecommunications Engineering curriculum.

A. Design and construction of a Switching-Mode Power Supply (SMPS)

An experimental prototype of a SMPS was designed and built in the practical sessions (7 sessions of two hours and 1 session of 1 hour) of the subject by each student. The assessment of this project focused on the student-learning process that becomes practical know-how. The end product (Fig. 1) was only evaluated as a part of the process. Therefore,

Figure 2. Laboratory student desk and devices to develop the practical sessions.

the application of the knowledge obtained in the theory classes is the goal of this project and the goal of the assessment.

At the beginning of the course, each student was assigned a laboratory desk with all the devices and instrumentation needed to develop the project. In the first session, students familiarized themselves with all the material. The rest of the practical sessions were divided into design sessions and building sessions. In the former, students had to design a part of the SMPS. In latter, students had to build this part. At the beginning of all these sessions, the lecturer briefly explained the concepts of the work to be done. All the lecturer's explanations have to be brief and to the point and have to drive student learning. After that, the students developed their part of the project with the lecturer acting as a mere facilitator, redirecting all the technical problems that arose during the session. At this point, the interaction of the students among themselves and with the lecturer is very fruitful because positive communication and a collaborative relationship is created. Moreover, as the sessions progressed, the lecturer raised challenging issues or questions that led students to in-depth exploration of authentic, important topics related to this part of the project. Student reflection regarding these issues was very important. All the concepts proposed at the beginning and all the questions raised during the class were carefully planned in each session. In the final session, students experimentally presented their SMPS prototype.

The lecturing team took special care with respect to the student-learning process. For this reason, tutorial classes were proposed to students when deficiencies in their knowledge appeared. Sometimes it was necessary to review and clear up concepts presented in classes.

B. Static study of a dc-dc converter topology

The second project undertaken by students was the static study of a dc-dc converter topology. The objective of this project only focused on obtaining theoretical knowledge.

The theoretical model to develop this static study was explained during theory classes with basic dc-dc converter topologies. Mid-course, a different project was proposed to each student. It is the lecturing team's belief that students have sufficient knowledge at this point to tackle a high-order problem. This project was the static study of a non-basic converter topology. In this case, the student role was authentic PBL: students were engaged problem-solvers, identifying the root problem and the conditions needed to obtain a good solution. They were also pursuing meaning and understanding, as well as becoming self-directed learners.

During the rest of the course, the student developed this static study in parallel with theory sessions in which the lecturer established similarities between the problems which had been solved during the course and the project to be developed. Yet again, a specific time for reflection was proposed by the lecturing team. For this reason, all the solved problems presented in the problem-solving classes were carefully planned after the project was launched. Finally, the project was presented as a MATLAB spreadsheet. In this project, tutorial classes were also fundamental.

IV. Assessment of Two Projects

A. Design and construction of a Switching-Mode Power Supply (SMPS)

The assessment of this project was planned differently from a traditional one. The lecturing team wanted to assess the learning process instead of the end product: in this case, a SMPS. The lecturer responsible for the practical sessions drew up a report on each student in every practical session. Thus, continuous assessment was carried out. The lecturing team thought that this project was particularly well suited to be included in a continuous assessment scheme in order to evaluate the main competency that students have to acquire: namely, application of the knowledge acquired in theory classes. Also, students presented a report with a thorough explanation of the tasks carried out during practical sessions. An experimental presentation and verification of the prototype was also conducted with the idea of promoting oral expression and public presentation in the final session.

The practical session reports drawn up by the lecturer, the final report on the SMPS design and the experimental presentation of the prototype were used by the lecturers to assess this project. This project counted for 30% of the final mark for the subject.

B. Static study of a dc-dc converter topology

The students presented a MATLAB spreadsheet (Fig. 3) with the solved static study of the proposed topology at the end of the course. They explained their solution to the lecturers and answered their questions with the idea of assessing the design process they had implemented. In this case, the goals of this assessment were to evaluate the ability to propose solutions to problems and to enhance critical reasoning to choose the appropriate solution. The fostering of oral expression and presenting in public were additional competencies likewise assessed in the presentation and defense of this project.

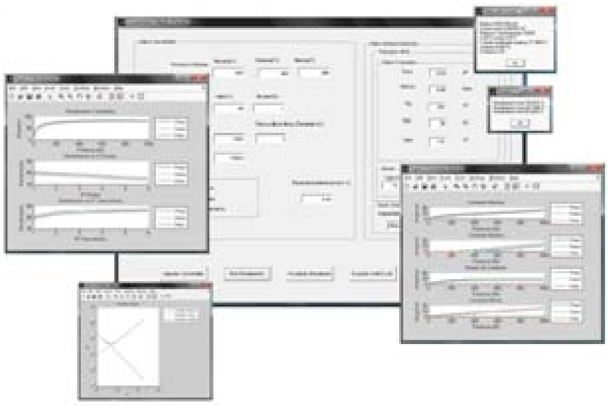

Figure 3. Example of a spreadsheat programed in MATLAB.

The project was assessed by means of a report on the presentation of the spreadsheet drawn up by the lecturer. This project counted for 20% of the final mark for the subject.

At the same time, a traditional exam was sat to complete the assessment of the subject, counting for 50% of the final mark.

V. STUDENT SURVEYS

At the end of the course, the lecturing team conducted a survey to ask students about the PBL methodology introduced in this subject. The results of this survey are shown in Fig.4. The main topics in this survey focused on the development of the main student competencies that the lecturing team wished to improve via this experience, the improvement of other skills and a general assessment of the subject.

As can be seen, students positively rate the improvement in their ability to solve problems, to apply the know-how acquired in theory classes and in their ability to make decisions. In fact, the opinion of the students can be summarized in a student comment that was common in all surveys:*" I enjoyed working in a power electronics laboratory developing the design of a converter very much. It is very interesting to solve real problems and to face challenging activities like this project"*

Other skills that students improved were reflected in the survey as positive issues: namely, the ability to search for and to assimilate information on their own, oral expression and writing technical reports.

Finally, the experience of this subject was also positively rated. As can be seen in Fig. 4, the students appreciated the planning time and the assessment of the subject. They were also very satisfied with the work carried out in the two projects forming part of the subject.

VI. LECTURERS' REFLECTIONS AFTER TWO YEARS. THE DIFICULTIES OF PBL APLICATION.

It seems logical that the assessment of this experience (the application of PBL) does not depend solely on student opinion. For this reason, the lecturing team established periodic interviews and meetings with students throughout the course. The results of this experience were thus deduced taking into

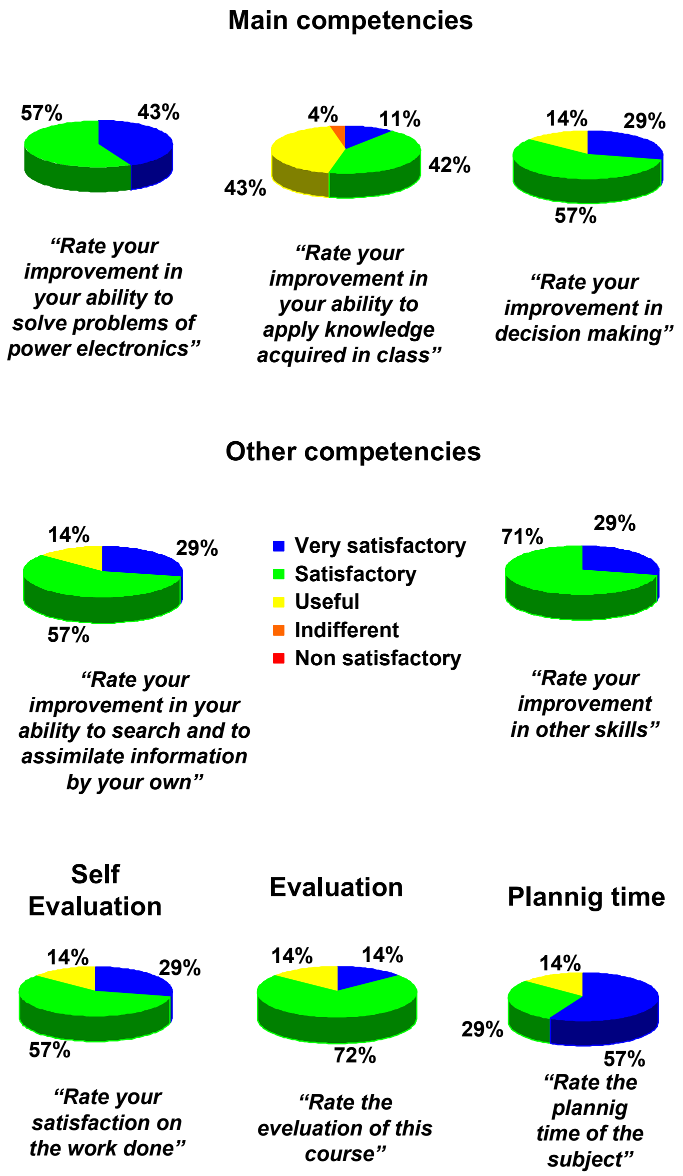

Figure 4. Student survey scores

account the surveys, meetings, interviews and final marks obtained in the subject. These results made us reflect on the application of the PBL as a new learning methodology. We conclude that the application of the PBL is neither straightforward nor easy. Including PBL in a subject curriculum presents a number of difficulties. We summarize our main reflections in what follows:

A. Student exam results were worse than their projects. Are we evaluating the learning process appropriately?

The results of both projects were very satisfactory from the technical point of view. All the students designed and built the SMPS prototype and obtained a certain benefit from the process, while the proposed static study was correctly developed. However, the results of the theory exam were worse

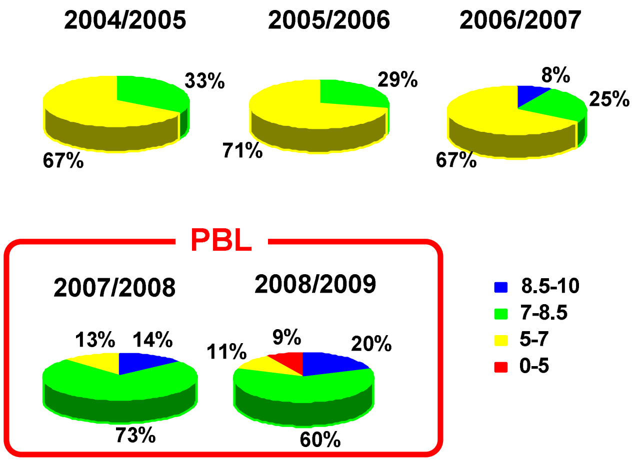

Figure 5. Marks obtained in the subject.

than expected. There were some mistakes in basic concepts developed in theory classes. We found that students apply acquired knowledge in practical projects as a "small recipes" in order to solve specific problems in project execution. Furthermore, they use a "blind" trial-and-error system to tackle the problems that arise in the projects. In both cases, although students solve their difficulties during the execution of the project, they do not acquire an overall view of the subject and significant learning is not achieved. These results lead us to think that we did not suitably assess the student learning process. We made a mistake: we assessed the results of both projects (the SMPS prototype and the MATLAB spreadsheet) but did not assess the student learning process. This fact is reflected in the final marks obtained in the subject. The marks for the last two years are better than the previous years when PBL had not been introduced in the subject. Figure 5 shows the marks obtained by the students in the last five years. Students fail if they get less than 5 marks out of 10. These marks are grouped in four intervals, which represent the qualification that is given to the student. As can be seen in Fig. 5, although most students passed the subject, the percentage of those who obtained the highest marks has increased significantly with the introduction of PBL in the subject. These results are due to the fact that the qualifications of the projects of the last two years are better than those of the practical sessions in the subject in the years 2004/2005, 2005/2006 and 2006/2007. However, the exam marks are equal to or worse than non PBL courses.

In order to improve the assessment of the student-learning process during the practical sessions, we intend to include rubrics in the present course (2009/2010). These rubrics will replace the report drawn up by the lecturer on each student in every practical session. These rubrics have been designed to carefully assess the main competencies to enhance: to promote the application of theoretical concepts and to provide the student with an ability to propose solutions to problems and to enhance critical reasoning. Also, this assessment methodology (the rubrics) will be applied to qualify the final report of the SMPS design, the MATLAB spreadsheet, the experimental presentation of the SMPS prototype and the defense of the static study. In this case, we wish to assess other competencies: the ability to write technical reports properly and the improvement in speaking in public.

B. Is the exam the greatest enemy of PBL?

Traditionally, PBL plus exam is a bad combination in a traditional course where the exam possesses the greatest weighting with respect to the final mark [10]. To implant PBL in a course requires a new perspective of the role of the exam.

According to our experience, the exams done by students are a continuous source of frustration to lecturers because the marks obtained by former are worse than the expectations of the latter. This is due to the fact that student projects, developed during the course, are generally very good. This fact may suggest that the subject should be only assessed by means of projects. From our point of view, however, all the efforts made during the course cannot centered around PBL. In fact, we only apply PBL in our subject to enhance a number of student competencies principally the application of technical and scientific knowledge acquired in theory classes. For this reason, we use theory classes to provide students with a broad view of the main concepts in the subject and to foster in them prior reflection before practical sessions. Therefore, we are convinced that theory classes are fundamental and we wish to highlight this conviction. As a consequence of this, the exam is necessary. Perhaps we have to rethink the role of the exam, bringing it more in line with the projects developed in the subject or planning the projects more in accordance with the exam. Another possibility is to plan an exam that ensures the basic concepts of the subject that students must have acquired.

C. We all have to accept that mistakes are necessary to learn

Student motivation was not constant throughout the two projects. The lecturing team expected student motivation and dedication to be very high when tackling real projects. This appreciation was however mistaken. The students were highly motivated during the first sessions. However, they have to master high-order reasoning as projects of this kind evolve. At this point, the students were found wanting in terms of their knowledge and the application of basic concepts acquired in theory classes. As a consequence of this, student motivation declined. Moreover, lecturer despair likewise increased. This situation (drop in motivation) was repeated during the project.

After two years of applying PBL in our subject, we must bear in mind that this is a normal situation in PBL and does not constitute a drawback. Lecturers and students have to accept that errors are necessary in order to learn and to apply acquired knowledge. It is very important for lecturers to make students aware of this fact in order to motivate them when problems arise. The motivation of both students and lecturers as the project evolves is like a "roller coaster". In some situations, the passengers (lecturers and students) might wish to get off the roller coaster. However, we have to keep up our motivation and that of our students in order to achieve the ultimate goal of PBL: significant learning.

D. *The time spent on PBL. A real change for lecturers and students*

First, lecturers need to be aware of the dedication that PBL requires. Monitoring, driving and implementing the work undertaken by students require time. The time spent on these activities is greater than the time spent on traditional learning methods. This is a new scenario that lecturers have to assume.

On the other hand, students have to plan their time during project implementation. It is normal for students to encounter problems in managing their own time, as they traditionally work on tasks planned by the lecturer. In each practical session, students only have to solve one planned problem. If students do not complete their tasks then they can redo this practical session at the end of the course because each practical session is self-contained. The problem to solve now is the project. The project presents a number of problems during its implementation and now the problems that arise presented are different for each student. The presented problems depend on the strategy used by the student to tackle the project. This situation seriously upsets student planning. Common student comments in practical sessions are: "it is too much work to develop in practical sessions", "we have to work a lot before practical sessions", etc. However, all students carried out the work planned by the lecturer in practical and problem-solving sessions and presented their assignments on time. Furthermore, surveys revealed that the time spent by students to prepare and develop both projects was less than the time scheduled by lecturers. These reflections show that students are not comfortable managing their own time.

E. *The application of PBL requires aninvestment in resources and facilities*

If a new active methodology is applied instead of traditional methods, then the facilities to develop this new methodology also have to change. Therefore a inversion in this methodologies has to be done [11].

The lecturing team is aware that this experience can be carried out because the number of students enrolled in our subject is low. "Sistemas Electrónicos de Alimentación" is an optional subject in the 5th year of the Telecommunications Engineering degree with an average of 12 students per course. For this reason, practical sessions of 6 students can be planned in our research laboratories to implement the SMPS project. However, this current year we have 30 students enrolled in our subject and so had to equip a new laboratory to develop the SMPS project. In this case, practical sessions of 10 students have been planned with two lecturers supervising the group in each session. As can be appreciated, PBL requires an investment in resources and facilities.

VII. CONCLUSIONS

Our experience in the application of PBL in the subject: "Sistemas Electrónicos de Alimentación" has been extremely positive for us and for students. However, we conclude that the introduction of PBL in our subject is upsetting for both parties. It implies difficulties which we are still solving after two years of applying PBL: facilities, assessment of the learning process, etc. We hope that the results obtained each year serve to improve the application of this methodology.

On the other hand, this methodology is appropriate to achieve the objectives proposed at the beginning of this experience. Students are motivated with this new scenario because they tackle and solve real problems in their projects. We have to benefit from this new atmosphere to guide students to significant learning. It is a great opportunity!

REFERENCES

[1] European Ministers of Education (1999). "The European Higher Education Area Bologna Declaration, Bolognia".

[2] L. Dee Fink "Creating Significant Learning Experiences: An Integrated Approach to Designing College Courses" San Frandsco: Jossey-Bass, 2003 xviii.

[3] D. R. Woods, "Problem-based learning: how to gain the most from PB". Mcmaster University 1994.

[4] Moursund D. "Project based-learning: using information technology". Iste publications 1999.

[5] L. R. J. Costa, M. Honkala, A. Lehtovuori, "Applying the Problem-Based Learning Approach to Teach Elementary Circuit Analysis", IEEE Transactions on Education, vol. 50, Issue 1, Feb. 2007, Page(s): 41-48.

[6] Mantri, A.; Dutt, S.; Gupta, J.P.; Chitkara, M., "Design and Evaluation of a PBL-Based Course in Analog Electronics," Education, IEEE Transactions on , vol.51, no.4, pp.432-438, Nov. 2008.

[7] Macias-Guarasa, J.; Montero, J.M.; San-Segundo, R.; Araujo, A.; Nieto-Taladriz, O., "A project-based learning approach to design electronic systems curricula," Education, IEEE Transactions on , vol.49, no.3, pp.389-397, Aug. 2006.

[8] Cheville, R. A.; McGovern, A.; Bull, K. S., "The Light Applications in Science and Engineering Research Collaborative Undergraduate Laboratory for Teaching (LASER CULT)-Relevant Experiential Learning in Photonics", Education, IEEE Transactions on , vol.48, no.2, pp.254-263, May. 2005.

[9] Mark Hedley, "An Undergraduate Microcontroller Systems Laboratory", Education, IEEE Transactions on , vol. 41, issue 4 , pp. 345-345.

[10] Miguel Valero-García, "Las dificultades que tienes cuando haces PBL". La educación superior hacia la convergencia europea: modelos basados en el aprendizaje (capítulo 8). Universidad de Mondragón.

[11] Valero García, Miguel y Navarro Guerrero, Juan José. "Diez metáforas para entender (y explicar) el nuevo modelo docente para el EEES". (2008) @tic. Revista d'innovació educativa. Nº 1, p. 3-8.