Project-Based Learning and Rubrics in the Teaching of Power Supplies and Photovoltaic Electricity

Fernando Martínez, *Member, IEEE*, Luis Carlos Herrero, and Santiago de Pablo, *Member, IEEE*

***Abstract*—Project-based learning (PBL) and cooperative learning are, in various aspects, very superior education methodologies compared to other traditional ones. They are highly appropriate methodologies for elective courses, as they exert a strong attraction on the students, quite apart from their educational advantages. This paper describes how PBL and cooperative learning have been used to teach the topics of power supplies and photovoltaic electricity within two elective undergraduate courses. A project is carried out for each of the two topics. Moodle is used as the e-learning platform to provide the course materials and the wiki resource and to allow the submission of assignments. The simulation is done by means of Simulink. Work has been done to develop skills for project planning, group management of the work, technical document writing and presentations in public. The methodology has been seen to be successful, as all the students who have followed it over the last few years have passed the courses in which it was included, Design of Industrial Applications and Industrial Electronics. Examples of the rubrics for assessing the projects and examples of the projects themselves are also included.**

***Index Terms*—Cooperative learning, Moodle, photovoltaic electricity, power supplies, project-based learning (PBL), rubrics, Simulink.**

I. Introduction

The European Union and Spain are in the process of adapting their university studies to the European Space for Higher Education, in compliance with the Bologna Declaration [1], signed by 29 countries in 1999. This implies a change toward the methodologies that focus on student learning, where cooperative learning, high-level learning (Bloom's Taxonomy) and the accreditation organizations (ENQA, ABET, ANECA, …) [2] will all play an important role.

In modern teaching methods, information technology, used in ways such as virtual laboratories and e-learning, has great importance. Virtual laboratories [3], [4] are increasing their presence as they allow 24-h/365-d work, which offers greater flexibility and lower cost. The e-learning platforms [5], [6] are a very important structural support for a course, through which students can download materials, simulation programs, and various types of exercises, and which can help to manage the group work and the delivery of students' work. There are both e-learning platforms designed for a specific application and general platforms, such as Moodle, which offer a diverse group of options and are oriented toward student-centered learning.

Project-based learning (PBL) began, in a structured way, in 1966, when the Faculty of Medicine of McMaster University in Ontario (Canada) was founded, with teaching based on "Problem-Based Learning." In the 1980s, it began to be used in some medical schools in the United States. Later, it moved to other areas of university education, and it is now an emerging methodology in Spain. Probably, with the advent of the European Space for Higher Education and the European Credit Transfer System (ECTS), this methodology will spread further.

PBL is a teaching strategy in which students, organized in groups, develop projects [7]. Its objectives are: to integrate knowledge and skills in several areas, develop high-level skills (above 3 in Bloom's Taxonomy), and promote independent learning and teamwork. The comparison between students taking courses with the standard methodology and with PBL indicates that the latter is more appropriate for courses in technology as students get a more general view, identify the problems and the relevant information better, and improve their social skills and the presentation of their work [8], [9]. PBL methodology also allows interdisciplinary projects, dealing with several subjects, to be undertaken; this is closer to the actual work of engineers and allows for a greater depth of learning [10]. A complete guide to the design of PBL can be found in [11], where all stages of the project design can be found along with assessment through rubrics.

Active and student-centered learning allows higher levels in Bloom's Taxonomy to be reached, with cooperative learning being the best methodology to achieve these. E-learning tools are well suited to implementing many types of cooperative learning activities [12], which may even contain Educational Games [13].

Project-Based Learning, an entity in itself, is part of a broader set of methodologies known as cooperative learning [14]–[16]. The advantages it has over other, more traditional techniques are that it:

- promotes the active involvement of students in the learning process;
- enables students to resolve their doubts themselves, sometimes more effectively than could the teacher, since their personal awareness of the specific difficulties of learning certain material is greater than that of the teacher;
- reduces dropout levels;
- promotes the development of critical thinking;
- increases student satisfaction with the learning experience and promotes a more positive attitude toward the subject of study;

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The authors are with the Department of Electronics, Escuela de Ingenierias Industriales, University of Valladolid, Valladolid 47014, Spain (e-mail: fer_mart@tele.uva.es).

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TABLE I
SYLLABUS FOR THE COURSE SECTIONS ON POWER SUPPLIES AND PHOTOVOLTAIC ELECTRICITY

POWER SUPPLIES
1. Switched Mode Power Supplies
a. HF Transformers
b. Control of DC/DC converters with isolation
c. Flyback converter
d. Forward converter
e. Push-pull converter
f. Half bridge converter
g. Full Bridge converter
2. Resonant Converters
a. Quasi-resonant converters
b. Load-resonant converters
PHOTOVOLTAIC ELECTRICITY
1. Solar Cells
a. Operating principles
b. Electrical characteristics
c. Photovoltaic modules
d. Module orientation
e. Peak power tracking
2. Batteries
a. Operating principles
b. Constitution
c. Charge and discharge processes
d. Effects of temperature
e. The photovoltaic battery
f. Precautions for use
3. Charge Regulators
4. Applications Design
a. Design of isolated systems
b. Design of grid-connected systems

- provides greater academic performance in math, science, and technology;
- prepares students for the work context;
- allows broader educational objectives to be achieved by having more points of view;
- promotes independent and self-learning;
- facilitates the development of communication skills, both written and oral;
- allows students' different learning styles to be accommodated.

In general, there are few courses in which PBL methodology is implemented. Therefore, some time should be spent motivating the students in this methodology, indicating its advantages and any difficulties they are going to find [17].

The heart of cooperative learning (or collaborative learning) is that students work together to complete a task in a class and have to pay as much attention to how their companions are learning as to how they are doing themselves [18]. Formal cooperative learning is characterized by the following five basic ingredients [14], [19], [20].

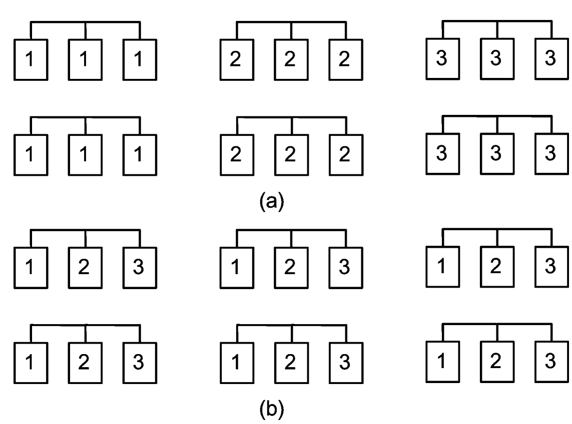

Fig. 1. Groups of three students for Jigsaw: (a) groups of experts; (b) base groups.

- Positive interdependence. This characteristic is the main element. The students need each other to complete the group's task successfully.

TABLE II
POWER SUPPLIES PROJECT

POWER SUPPLIES PROJECT
The project consists of the design of a power supply, of one of the following types (choose): flyback, forward, push-pull, half-bridge, full-bridge, resonant. *Power supplies are fed from a voltage of 310 V DC. They must have two outputs: 5V/10A, 15V/3A.* *The project must take into account the following guidelines:* *1. Performance in stationary state for different load levels. Performance must be proved by the following evidence:* *Verify both outputs when the load is 100% at both outputs.* *Verify both outputs when the load is 100% at output 1 and 10% at output 2, and when the load is 10% and 100% respectively.* *Verify both outputs when the load is 10% at both outputs.* *2. On and off transitions. Check the voltage waveforms of the two outputs, when switching the supply on and off.* *3. Load transients. Check the voltages of the two outputs when the load varies from 10 to 100% at one output. Verify the same, when the load variation occurs in the other output.* *4. Semiconductors used in the supply must be chosen by searching on the Internet.* *5. The project should be carried out using Simulink, the literature and the Internet. The result should be based on these sources, but be different from them, and may not be a literal copy of these sources. The sources used should be listed.*

- Face-to-face interaction. They have to work together, share resources, and help each other.
- Individual accountability. This is achieved by allocating different roles to group members.
- Interpersonal and small group skills. Social skills are essential for effective collaboration.
- Group processing. Finally, the evaluation of the group processing is completed by individual students, other members of the group, and other groups.

Students of electronic engineering and telecommunications engineering are taught the topics of power supplies and photovoltaic electricity in their sixth semester at the School of Industrial Engineering, University of Valladolid, Valladolid, Spain, within two elective courses, Design of Industrial Applications and Industrial Electronics. Students must choose their elective courses from a wide range available in the fields of electricity, electronics, control, and communications.

In the subject area of power supplies, isolated converters [21] and resonant converters [22] are studied, while the nonisolated converters will have been studied by students in their required courses. In the photovoltaic subject area, the components of the applications and the design of typical installations, such as home electrification and grid connection, are studied.

Previously, these subjects were taught by means of a traditional methodology: theory, problems, and practicals. Currently, the methodology used is PBL, and one project is done in each of the two subject areas. This increases the students' motivation and gives the teachers the opportunity to encourage such skills [23] as teamwork, writing technical documents, and the design of technical presentations.

For the power supplies project, the aim is to design an isolated or resonant power source. Students must demonstrate that it meets the specifications originally given, performing a simulation with Matlab/Simulink [24], [25], and present the project by means of a poster. In the photovoltaic electricity project, students must design an isolated or grid-connected photovoltaic application, using commercial elements chosen on the manufacturer's Web sites. The presentation of the work is done using PowerPoint. All the deliverables that the students have to deliver are evaluated based on rubrics [26], [27], a set of criteria linked to learning objectives used to assess the students' performance. These are provided to the students at the start of the project so they know clearly what are the quality standards demanded in each part.

The classroom has computers for all the students, loaded with Office, Matlab/Simulink, Moodle [14], [28], and Internet access. Through Moodle (www.dte.eup.uva.es/moodle19), materials are supplied, assignments are collected, and the wiki resource is provided to the working groups.

II. CONTENTS

The two optional courses, Design of Industrial Applications and Industrial Electronics, in which the power supplies and photovoltaic electricity material is taught, are described in greater detail in the Section III. This section describes this material, while the following section explains the methodology used to present the theory and methodology for carrying out projects.

In the area of power supplies, the fact that the students have already studied dc/dc converters without isolation in a prerequisite course, Power Electronics, must be taken into account. The

TABLE III
PHOTOVOLTAIC ELECTRICITY PROJECT

PHOTOVOLTAIC ELECTRICITY PROJECT
Students are required to select a project from the following. *Project 1: Design of the electrification of a home for weekends and holidays.* *Project 2: Design of the electrification of a home for permanent use.* *Project 3: Design of a photovoltaic system for grid connection.* *Project 4: Design of the electrification of housing, mixed photovoltaic and wind power.* *Project 5: Design of the electrification of housing, mixed photovoltaic and diesel generator.* *First, the document "Reprocessing of the wording of the project" must be prepared, as it is a definition of specific objectives for the project. To do this, students must use the relevant rubric.* *The project must take into account the following guidelines:* *1. The report of the project should have as a main focus (more than 80% of content) aspects included in the course syllabus: solar panels, regulators, batteries, inverters and design. Other aspects of interest in the group can be included, up to 20% of the contents of the report, such as grants, elements of the installations (electrical, civil engineering, consumer appliances, installation of solar tracking, ...), wind turbines, diesel generators, commercial design software, …* *2. The project will be carried out using the literature and the Internet. The result should be based on these sources, but be different from them, and may not be a literal copy of these sources. The sources used should be listed.*

contents of the elective concentrate on isolated power supplies and resonant supplies, as can be seen in Table I. The following observations can be made.

1) High-frequency transformers are introduced: equivalent circuit, unidirectional and bidirectional flux, and saturation.
2) PWM control for converters is introduced: diagram of a feedback power supply, isolation, converters with a single transistor or several transistors, converters with several outputs.
3) The same type of study is made for all kinds of converter: The waveform of the voltages and the currents in the transformer windings and the semiconductors are analyzed, the input–output voltage ratio when stationary is calculated, and the voltages and peak values of the current in the semiconductors are also calculated.
4) The different types of converters are compared so as to be able to choose the most appropriate for each power range.
5) For resonant converters, there is an introduction that explains their interest due to the low power dissipation in the commutations. For quasi-resonant converters and resonant converters, only some of the possible topologies are studied, such as zero-current-switching quasi-resonant buck, zero-voltage-switching quasi-resonant boost and parallel-loaded resonant. The different modes of functioning, the waveforms, and the input–output voltage ratio are studied in all of these.

Photovoltaic electricity is new for the students. In this subject area, they study (Table I) the main components of a photovoltaic installation, together with the design methodology for insulated or grid-connected installations. Some of the topics covered are the following:

1) the study of the solar cell includes: the photovoltaic effect, its characteristics as an insulated element, its association in array to make solar panels as well as considerations for the use of such panels;
2) an exhaustive explanation is given of the lead-acid batteries, including: the chemical reactions, the components of commercial batteries, the effect of temperature and what must be taken into account when considering photovoltaic applications;
3) the use of charge regulators in mains insulated applications;
4) the design of insulated installations: calculation of the available radiation, calculation of the number of solar panels and batteries needed;
5) the design of installations connected to the mains: calculation of the available radiation, calculation of the number of solar panels, requirements for mains connection.

III. METHODOLOGY

The authors have used PBL methodology in two courses [29].

1) "Design of Industrial Applications," an elective course in the Electronic Engineering program. This six-credit course is taught in the sixth semester and has incorporated PBL since 2005. Enrolment was 27, 22, 22, and 33 students for each year since then, respectively.
2) "Industrial Electronics," an optional course in the Telecommunications Engineering program. This 4.5-credit course

Fig. 2. Moodle platform for the subject Power Supplies.

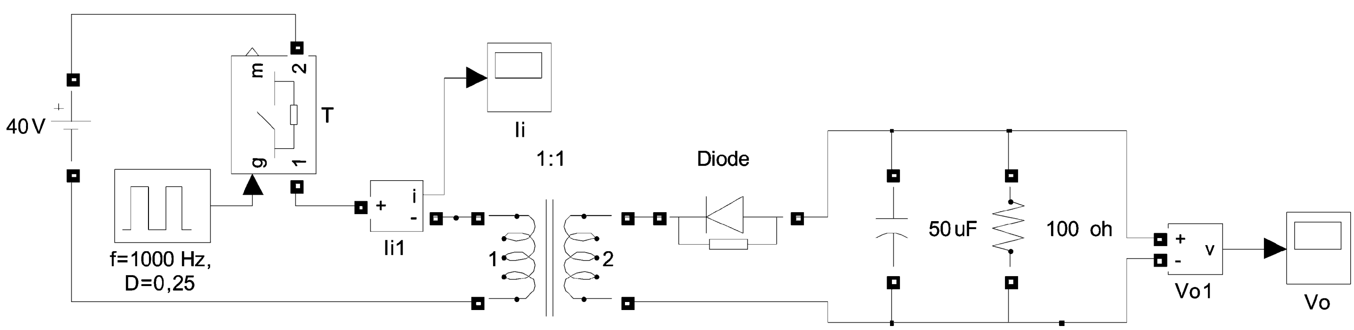

Fig. 3. Flyback converter simulated using Simulink.

is taught in the sixth semester and has incorporated PBL since 2004. Enrollment was 9, 13, 15, 11, and 8 students each year since then, respectively.

Both courses included two projects, the first about power supplies and the second about photovoltaic electricity. The second course included a third project on another topic unrelated to the scope of this paper. The projects were conducted in groups of four students who stayed together for all the projects. For each project, students had to develop several intermediate and final deliverables. Not only the final result, but also the intermediate results, are required, so as to be able to provide feedback to students on their degree to which they have met the project objectives. The interim and final deliverables requested are as follows: reworking the wording of the project, planning, interim versions of the report and presentation, minutes of the group meetings, and final version of the report and presentation.

Throughout the development of the PBL methodology for these courses, a number of difficulties has emerged. The first is that there are projects where the theory is extensive and complex, which delays the start of the projects. To avoid this difficulty, the end of each project has been overlapped with the explanation of the theory of the next project. Thus, a project can be started immediately after the completion of the previous one. Second, it is difficult for students to understand the standard of quality required; therefore, the first project should be evaluated as soon as possible so that students have feedback on how to assess their work before carrying out the second project.

The academic results from these courses were that all students who participated in the project groups passed the course. There were only two students who were unable to follow the PBL system due to personal circumstances.

The interim and final results that are requested are as follows.

1) Reworking of the project objectives, making them more specific to the interest of the group. If the project objectives are detailed and specific, the work will start earlier.
2) Planning for the project. The planning allows the work to be spread evenly throughout the available time and to employ all the available human resources in the most appropriate way for the project's objectives and the time available.

TABLE IV
RUBRICS USED IN THE EVALUATION OF PROJECTS

REPROCESSING THE WORDING			
	High (7-10)	Intermediate(4-7)	Low (0 – 4)
	The specific objectives are totally clear and feasible with the tools and time available. A person outside the project would do the same project from this formulation.	The specific objectives are quite clear and are probably feasible with the tools and time available. A person outside the project would have to resolve some doubts from this formulation.	The specific objectives are unclear or are not feasible with the tools and time available. A person outside the project could make a project very different from the original statement.
PLANNING			
	High (7-10)	Intermediate (4-7)	Low (0 – 4)
	All tasks are concretely distributed and appropriate to the time scheduled. The activities are well connected.	Most of the tasks are concretely distributed and appropriate to the time scheduled. Activities are related.	Activities undefined and/or non-differentiated. Activities very isolated.
REPORT			
Criteria	High (7-10)	Intermediate (4-7)	Low (0 – 4)
Well written, clear, well formatted (15%)	The document does not have misspellings, and a simple language is used that is understood perfectly. The document is well prepared. It has a pleasant aspect, the pages, drawings, etc., are numbered. The different sections are clearly distinguishable. It is evident that the work has been approached seriously.	The document is understandable, although some parts could be improved. I have found some errors, probably attributable to confusion. With a little more effort, it could have been better. Uniform format.	I found several misspellings, and I did not understand much of what is said in the document. The document is quite slipshod. It shows that they have not done much. Colloquial expressions are used on a regular basis.
Good approach to the project (20%)	The approach is good. I cannot think of many improvements. The structuring is clear. The procedures that will be used are well described. With this explanation, I believe that I myself could carry out the project without any difficulty, and without having to ask the group that actually did it many questions.	I believe that the approach is good although it admits of some improvements. I understand well what they want to do, but if I had to implement the project I would have to request some additional explanation.	The approach is not good. I do not understand the intention or the necessity of some of the elements, or some of the procedures. If I had to implement the project with this information, I would not know where to begin.
Content (35%)	Provides comprehensive, accurate and relevant information. Based on an extensive and careful investigation. The breadth and depth of work are very high for the set time.	The information is partially complete, accurate and relevant. Based on a proper investigation. The extent and depth of the work are appropriate for the set time.	The information is vague, irrelevant or incorrect. Based on a minimal investigation. It is evident that there are several parts copied and without elaboration. The extension and/or depth of the work are insufficient for the defined time.
Critical analysis (15%)	In addition to the intermediate criteria: it uses its own analysis to explain the definitions, laws, concepts and principles under study.	It demonstrates a clear understanding of the rules, definitions, laws, concepts, theories and principles of the object under study. It includes diagrams, models, figures, step by step evolution of the object under study. The existing relations between ideas, data or phenomena are demonstrated.	It does not demonstrate that the work has been understood. The analysis does not include figures, models, definitions, parts of the problem/object under study. The cause-effect relations are not identified.
Graphics: figures, tables and formulas (15%)	The work is supported by carefully chosen graphics, and with appropriate titles.	The work is supported by graphics. There are some that are not appropriate and/or whose title is not appropriate.	The graphics help little in understanding the content, or are irrelevant. The titles of these are not appropriate. There are low-quality graphics.
PRESENTATION			
Criteria	High (7-10)	Intermediate (4-7)	Low (0 – 4)
Content (30%)	The information is complete and well-supported in detail. The knowledge acquisition that occurs when hearing the presentation is significant.	The information is complete, with a detailed support base. The knowledge of the audience is increased in some aspects.	Lacks important information. There are no details that help understanding.
Organization, development and vocabulary (40%)	The introduction indicates the targets and captures the attention. The development is organized and has detailed support. The conclusions indicate in detail the most important points. The vocabulary is rich.	The introduction indicates the objectives but does not capture the audience's attention. The development is organized and has some support. The conclusions indicate basically the most important points. The vocabulary is appropriate, with some slips.	There is no introduction, or it is not clear. The development is confusing and has no support tools. No final conclusions are given or they are not clear. The technical vocabulary is limited.
Visual aids to the presentation (30%)	Clearly help the presentation and increase the ease of understanding.	Are appropriate to the subject, but the integration is not optimal.	Do not help the audience. They are confused.
RECORD OF THE MEETINGS			
	High (7-10)	Intermediate (4-7)	Low (0 – 4)
	The number of meetings has been appropriate. The acts are concrete and detailed.	The number of meetings has been quite appropriate. The acts are quite concrete and detailed.	The number of meetings has not been appropriate. The acts are general and have little detail.

3) Intermediate version of the report and presentation. This serves to provide feedback to students when about half the project time has passed. This does not eliminate the continuous feedback that occurs through student–teacher dialog.

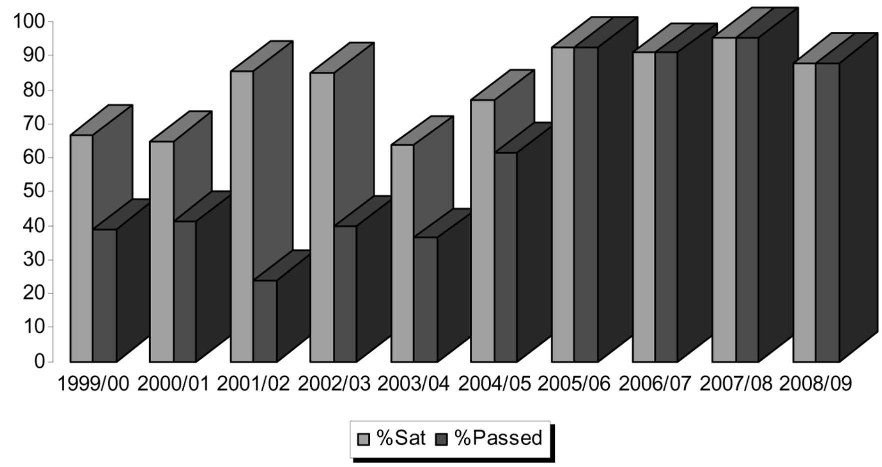

Fig. 4. Percentage of students passing the course Design of Industrial Applications.

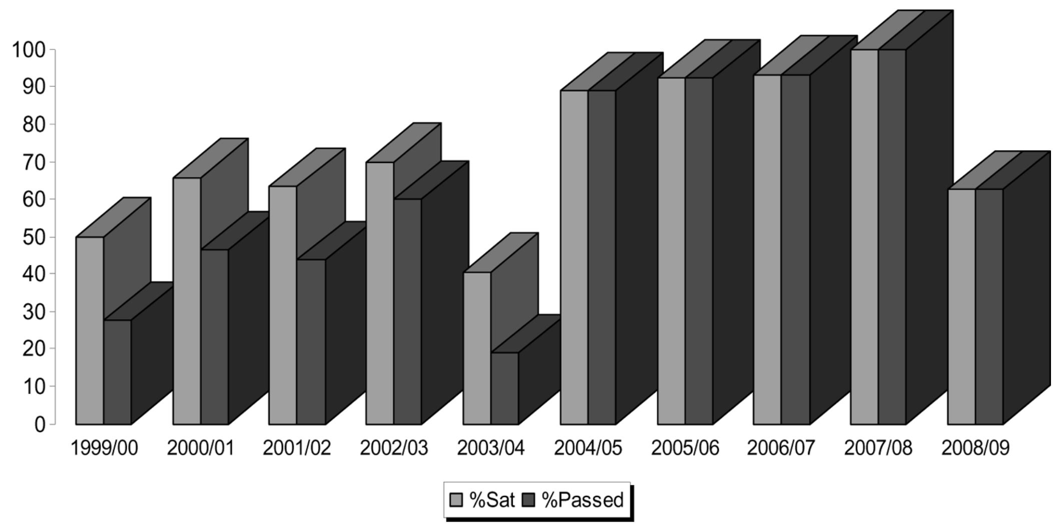

Fig. 5. Percentage of students passing the course Industrial Electronics.

4) Minutes of the meetings. Students were asked to make minutes of meetings to help the groups' planning. Each group must have at least a coordinator and a secretary.
5) Final version of the report and presentation.

The time allocated for such projects is 90 h per student, 45 h in class and 45 h for work outside the classroom.

The presentation of the theory, whose contents are shown in Table I, is done through lectures and a type of cooperative learning activity called "jigsaw" [28]. The lectures are used to give an overview of the issues for the most complex aspects and for those parts where it is difficult to find an adequate bibliography. The jigsaw method is used in other parts of the theory. It has the advantage of keeping the students more active, increasing their efficiency, and promoting the interaction between people who usually do not work together, so they discover other ways of working.

In the jigsaw cooperative learning method, after dividing the field of study into three parts, base groups and expert groups are created (Fig. 1). First, the groups of experts [Fig. 1(a)] analyze each part of the field of study. Then, students work in base groups [Fig. 1(b)] where each member of the group is an expert in one-third of the field of study, sharing the part studied in the expert group with two other students in the group.

In the area of power supplies, the nonisolated dc/dc converters are not included since these are covered in the compulsory courses taken in the Power Electronics program. The two topics covered are isolated dc/dc converters and resonant converters. The section on converters includes high-frequency transformers and the methodology of control of PWM converters. Students have specific material written by the authors, which is used to assist in the presentation of the theory and in the implementation of the jigsaw method.

IV. Structure of the Projects

The definition of the first project (in the area of power supplies) is more detailed because it is the first time this methodology has been used by the students. The second (in the area of photovoltaic electricity) is less detailed because students are better trained in project management and are more able to make a definition. Some examples of these projects are shown in Tables II and III.

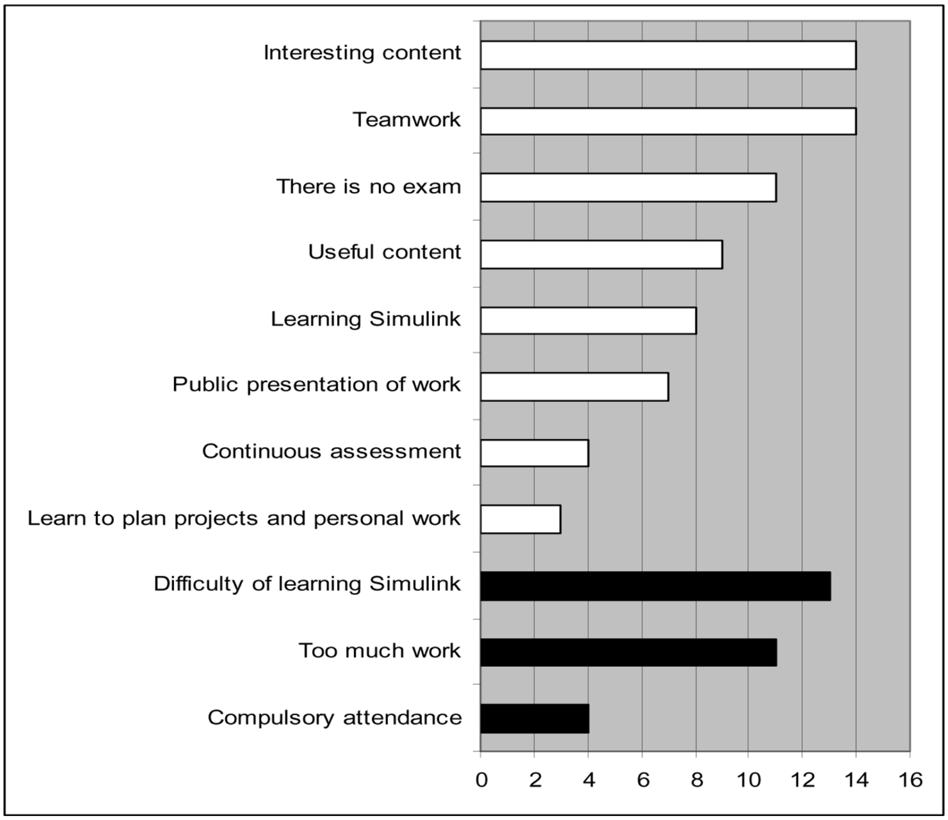

Fig. 6. Student surveys in 2007–2008.

V. Use of Moodle and Simulink

The platform Moodle is a powerful environment for managing a course that uses an active methodology [14], [28]. It also has the advantage of being free code. These courses use the following Moodle capabilities (Fig. 2): providing written materials, proposing exercises, and collecting and storing the exercises. It also provides students with an option called wiki, which allows the report of the project to be written collaboratively.

The material supplied includes the theory, the definition of the projects, training on teamwork, template PowerPoint presentations, rubrics and exercises for the use of such rubrics, and simulation exercises with Simulink. Students have examples of the major tasks they are asked to perform: project planning, report, and presentation.

Students do exercises to learn how to perform the planning, reporting, and presentation of each project correctly. Using Moodle, two examples of work done in previous years (planning, report, or public presentation) are provided, together with the evaluation rubric. They should evaluate such work under the rubrics provided. Subsequently, the teacher provides the evaluation of the work so that students can compare it with what they have done.

The Moodle platform has great advantages in the management of student work. Students have a clear timetable with all the deliverables that have to be provided, together with their manner of delivery. Teachers do not need to devote time to seeking work or organizing its reception. They can evaluate the work submitted from any computer connected to the Internet.

A utility greatly appreciated by the students is wiki, which allows the project report to be written up in a collaborative form, with the document that is being written being kept on the server so that all the members of the group can work on the most recent version of the document.

Simulink is not a free code program, but students have free access to a computer lab where this is available, and they can also buy a student version at a greatly reduced price.

Two examples are provided of power supply circuits, made on Simulink, to accelerate the design process, because the students' knowledge of Simulink is low or nonexistent. The first example is a circuit with resistors and voltage sources to learn how to run simulations and measure voltages and currents. The second (Fig. 3) is a flyback converter, where students can find examples of how to configure the PWM modulator, the switch, and the transformer, the components that may pose greater difficulties.

VI. Assessment

Assessment of each project takes into account the following.

1) Report on the project is worth 60% of the course grade and is assessed against to the relevant rubric.
2) Presentation. Students present their work to the rest of the class in two different ways, for the first project through a poster and the second through a PowerPoint presentation. This is worth 20% of the course grade, according to the relevant rubric.
3) Quality of the teamwork is worth 20% of the course grade and consists of the following components:
— reprocessing of the project specifications;

— planning for the project;
— minutes of the meetings.

VII. Rubrics

The rubrics are an excellent way to establish communication between the student and the teacher about the evaluation criteria and what the quality standard demanded by the teacher is. They allow the student to know, right from the start, how to do their work individually and in groups. In addition, it is a fair assessment of the student's work, known in advance.

Rubrics can be used to evaluate very different kinds of technical projects and skills (writing articles, Web sites, billboard business, speech, oral presentations, research articles, critical thinking, teamwork, information search, selection of information, planning personal time, planning group time, …) [11]. There are two types of rubrics: holistic and analytical. Holistic rubrics evaluate the full work of the student without dividing it into parts or components. Analytical rubrics divide a product from a student into several components and evaluate each of these parts. The mark is obtained based on the qualifications of the parts. The advantage of analytical rubrics is that they offer more feedback to students and so enable them to make a better product [30].

In this course, rubrics were used for all the elements that make up the student's evaluation: reworking the wording of the project, project planning, report, presentation, and minutes of meetings. The rubrics are detailed in Table IV.

VIII. Academic Results

The new methodology was first used in 2005–2006 in the course Design of Industrial Applications and in 2004–2005 in the course Industrial Electronics. The use of this methodology has substantially improved the percentage of students sitting the examination and the percentage of those who pass the course, as seen in Figs. 4 and 5. Another remarkable thing about this methodology is that all the students who followed it passed the courses, although it should be emphasized that these are elective courses and that students who choose them are motivated to participate in a methodology of this type.

Since this methodology has been used, there has been a large increase in the number of enrolled students. This is an important aspect, especially when the electives must compete to get student enrollment. In this case, the increase in enrollment has been 56%.

IX. Student Surveys

In both courses, surveys measuring student satisfaction were carried out. They were asked about the positive and negative aspects of the course in an open-ended manner. The survey results for the year 2007–2008 are presented in Fig. 6 and show the answers that are repeated most often (positive in white, negative in black). Students feel very positively about the contents and the teamwork, the assessment without exam, the learning of a new simulation platform such as Simulink, and the skills of public presentations and project planning. The two most significant negative responses were for the difficulty of learning Simulink and the amount of work required. To address these concerns, the time spent learning Simulink can be increased and the amount of work required should be better adjusted to the time available.

X. Conclusion

In this paper, the teaching of the topics power supplies and photovoltaic electricity with PBL methodology and the incorporation of this within elective courses have been presented. In this approach, great importance has been given to the use of rubrics, Moodle, and Simulink. This enabled very positive results to be achieved, as all the students who participated for the past five years passed their courses. The methodology exercised various skills in addition to conveying the specific subject matter. Surveys show that students have a very positive view of these courses. Therefore, it is considered that this approach is very appropriate for electives, as it encourages student enrollment.

The rubrics used for the different aspects assessed have been included. These aspects are: reprocessing the wording, planning, report, presentation, and record of the meetings.

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Fernando Martínez (M'10) received the B.Sc. degree from the University of Valladolid, Vallodolid, Spain, in 1988, the M.Sc. degree from the National University of Distance Education, Spain, in 1997, and the Ph.D. degree from the University of Valladolid in 2004, all in industrial engineering.

He has been with the Electronic Technology Department, University of Valladolid, since 1984, first as an Assistant Professor and since 1994 as Associate Professor. His academic expertise includes analog electronics, power electronics, and new teaching methodologies. His current research interests are power converters for motor control, photovoltaic and wind applications, and cooperative learning.

Luis Carlos Herrero received the B.Sc. (Hons.), M.S.E.E., and Ph.D. degrees in electronics engineering from the University of Valladolid, Valladolid, Spain, in 1986, 1992, and 2005, respectively.

Since 1994, he has been an Associate Professor with the Electronic Technology Department, University of Valladolid, engaged in the development and design of analog and digital power electronics systems. He teaches courses in power electronics. His main research areas are direct ac/ac converters, new converter topologies, and power electronics conditioners with PWM sliding inverters for ac motors controllers and photovoltaic systems. Currently, he is involved in research and development of industrial projects in the areas of photovoltaic (CC/CA) and wind generators (CA/CA).

Santiago de Pablo (M'07) received the M.S.E.E. and Ph.D. degrees in electrical engineering from the University of Valladolid, Valladolid, Spain, in 1992 and 1995, respectively.

From 1992 to 1997, he was an Assistant Professor with the University of Valladolid. Since 1998, he has been an Associate Professor with the same university. His research interests include power electronics, ac drives, PWM modulation techniques, control systems using FPGA, and processor design. Currently, he is involved in research and industrial projects in the areas of wind generators and ultrasound systems for medical applications.