AN INTERACTIVE PROJECT-BASED TEACHING METHODOLOGY IN ELECTRICAL ENGINEERING COURSES

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A teacher-centred pedagogical approach and a technical content disconnected with real world industry applications are two of the main causes that explain a low motivation in engineering studies. This work proposes a learner-centred interactive methodology together with a project-based teaching to overcome both problems and achieve a life-long learning. The proposed methodology is successfully applied to different subjects in the Electrical Engineering studies at the University of Málaga.

Key words: Project-based teaching, Electrical Engineering, Interactivity

1. Introduction

Students at engineering studies often show a low motivation in their studies [1], and this has been specifically addressed in Electrical Engineering subjects [2]-[4]. There is not a single cause for this fact, existing many dimensions that affect students' attitude in a higher or lower degree [5]. Previous studies point at different dimensions being responsible for this lack of motivation [6], concluding that two of the main causes are:

- ✓ A teacher-centred model of instruction, where the development of the instruction and control of the learning process is retained by the teacher. In this framework, there is the assumption that the teacher needs to do things ''to'' and ''for'' the learner. In other words, the teacher manipulates the learning situation to obtain the desired outcomes guided by generalized characteristics of the learners [7]. The teacher-centred methodology usually leads to rote learning and stifling of critical and creative thinking [8], [9].
- ✓ The students do not properly feel the relationship of the technical content of the subject and the real industry applications [10]. Learners are often told that they will realize about the usefulness of what is taught "later on". However, if the student is not directly involved in a context where the industrial application is immediate, the learners' motivation can be affected.

These conclusions are in complete agreement with the methodological guidelines highlighted within the European Higher Education Area (EHEA) where the life-long learning, learner-centred teaching and practical knowledge are promoted [11]. Considering this two main features of traditional teaching as the main influencing factors on student's inadequate attitude, a modified teaching methodology is proposed in this work. It includes three main characteristics:

- ✓ A *project-based approach.* In order to involve the student in real world applications, some projects are included in the curriculum. These projects are samples of the industry applications where the knowledge of the subject can be applied. The projects include further technical content that lies outside the subject boundaries but that is useful to improve students' motivation. For example, if a project about electrical vehicles (EVs) [12] is included in an Electrical Machine's course, the project describes the electrical drive elements, the control scheme, the type of motor and batteries and the EVs elements.

- ✓ A *learner-centred approach*. Learner-centred practices move the focus from the teacher to the student, paying more attention to the learning performance rather than the instruction methodology [6]-[8],[13]. According to this second approach, learning is viewed as a natural and constructive process. Furthermore, if the learning is more meaningful and relevant to the student, the teaching efficiency is also increased. The proposed methodology includes the projects within an interactive methodology that groups the students, promotes discussions, improves transverse skills and favours the learner's active role.
- ✓ *Use of new technologies*. There is a major trend of using new technologies as pedagogical tools. Inside asynchronous methodologies, e-learning and virtual labs have been design and implemented, giving the student the possibility of remote access [14-16]. However, the use of the new technologies in these contexts is not completely useful to break the teacher-centred teaching and promote the students' interaction and collaborative attitude. The present proposal includes simulations of the projects used during the course with the aim of improving the understanding of some concepts, the visualization of several phenomena and to provide an attractive environment [4].

The three features above explained are combined to enhance traditional methodology, not to substitute it. This is shown in Fig. 1 where the scheme of the traditional and proposed methodology is depicted. Standard chalk-and-board is maintained in some parts of the course because it is very useful to simultaneously teach the main concepts to all the students at the same time, especially in courses with a high number of students. Nevertheless, the combination of the lectures with some classes where the students work in groups aiming to solve real-world problems within a motivating context can improve the students' performance. Many experiences with a project based approach are reported in literature [17]-[19], even proposing curriculums strongly based on projects as is the case in Aalborg University [20]. The authors have preferred to use a mixed methodology aiming at obtaining the advantages of both ways of teaching. It must be highlighted here that the present proposal is in complete accordance with the forthcoming changes in the engineering degree structure as a consequence of the convergence with Bologna. Although the projects are used in this experience in a synchronous way using an interactive and collaborative methodology, these projects can be immediately used for asynchronous teaching used as tasks for the students within the subject. Finally, the idea of the innovation is not to use this new teaching approach in a single subject, but to coordinate its use in three subjects that are representative of the electrical engineering curriculum. The proposal is simultaneously applied to: electrical machines, industrial design and theory of circuits courses. This coordinated manner of implementing the teaching innovations has to main advantages. Firstly, the students can see coherence in the teaching process of electrical engineering matters and this has a synergic effect since the student is accustomed to play a more active role. On the other hand it is possible to create a data base of electrical engineering projects for real world industry applications. The paper is structured describing the subjects and the traditional teaching in section 2, showing some samples of the projects in section 3, detailing the interactive methodology used for the project teaching in section 4, showing some results in section 5 and extracting some conclusions in section 6.

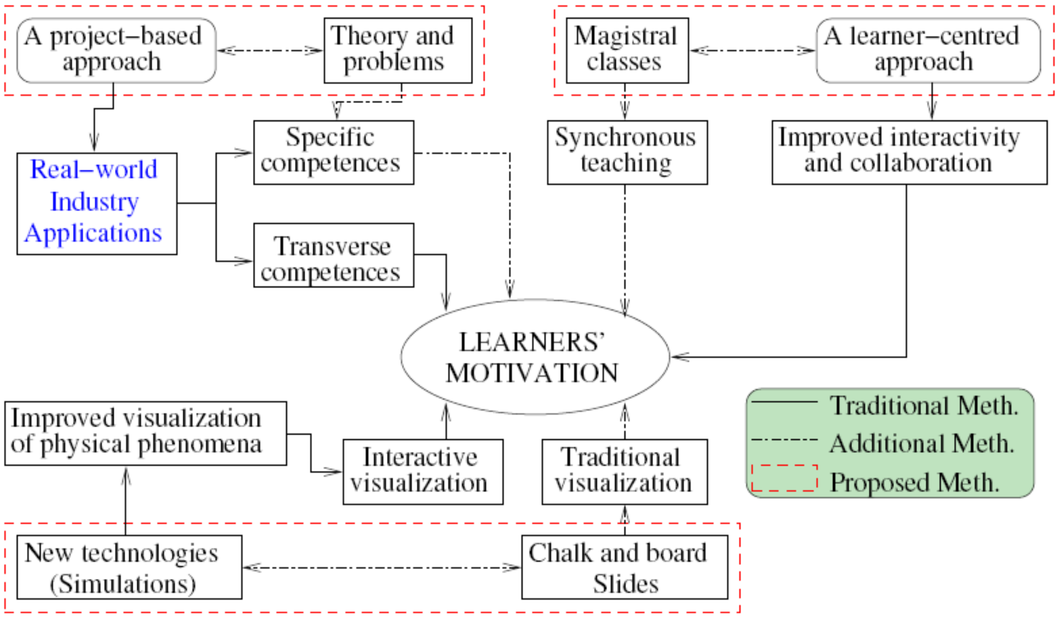

Fig. 1. Scheme of the traditional and proposed methodology.

2. Subjects involved in the innovation and traditional teaching

Three subjects are involved in the teaching innovation. They are all related to electrical engineering topics and lectured in the School of Engineering of the University of Málaga:

2.1. Electrical machines (EM)

This subject is lectured to second course electrical engineering students within the second semester of the year. It has 6 credits equivalent to 60 lecturing hours and it has on average 50 students in each of the two groups. The subject is compulsory to all electrical engineering students. The content of the subject includes the dc and synchronous machines (transformers and induction machine have being previously explained in another subject in the first semester of the second year). EM courses in general have already being reported as subjects where the engineering learners find difficulties to deeply understand the main concepts involved [4]. The traditional teaching consists of:

- ✓ *Theory lectures*: 40 hours are used to explain the theoretical concepts. These are chalk-and-board classes where the fundamentals are explained to the student. Since it is more a scientific rather than a technological subject, most of the time the professor refers to the physical models instead of pointing out any specific application.
- ✓ *Problems*: 35 hours are used to solve some problems. These problems are solved using slides or chalk-and-board methodology. This subject is key for others in the electrical engineering curriculum, so it is considered as important that the learner properly acquires the skills to solve all kind of circuits.
- ✓ *Practical classes*: 15 hours are dedicated to let the student practice in the laboratory with real resistances, inductances, capacitors voltage sources, etc.

2.2. Electrical Circuits (EC)

EC is a second-year course subject within the industrial engineering degree. It has 90 lecturing hours, an average of 60 students per class and it is lectured during the two semesters of the academic year. The content of EC includes the techniques of analysis, dc and ac circuits in steady state, three-phase circuits and transients. EC has also shown difficulties to learners [14], and some innovations have been proposed to enhance the methodology in this subject. The traditional teaching consists of:

- ✓ *Theory lectures*: 30 hours are used to explain the theoretical concepts and to solve some simple examples. The examples are included within the theory and are shown after each concept that implies some difficulties for the learners.
- ✓ *Problems*: 16 hours are used to solve some problems with a higher degree of difficulty than the previous examples shown in the theoretical part. These problems are solved using slides (usual power point presentations) or chalk-and-board tools.
- ✓ *Practical classes*: 14 hours are dedicated to let the student practice in the laboratory with real machines and electrical apparatus.

2.3. Industrial Design (ID)

ID is a second-year course subject lectured within the second semester of the design engineering degree. It has 45 lecturing hours and 15 students per class on average. The content of ID includes the calculus of the cables and protections in the design of electrical installations. ID subject shows some difficulties in the teaching learning process because the students come to the subject with different electrical engineering background. The traditional teaching consists of:

- ✓ *Theory lectures*: 36 hours are used to explain the theoretical concepts and to solve some examples and problems. The problems are included within the theory and are taught using standard slides or chalk-and-board tools.
- ✓ *Practical classes*: 9 hours are dedicated for lab classes to reinforce the theoretical lessons.

3. A project-based approach

3.1. Individual projects.

The concept of the project-based teaching has been already applied in different topics and degrees. Some experiences have even created the whole curriculum of a degree based on project. In the present experience, the projects are used to challenge the students and provide them with some interesting applications of electrical engineers. The projects are selected to enhance key topics in the content of each subject and are applied in specific classes within the subject schedule. The projects complement the traditional teaching: main concepts are simultaneously taught to all students in standard lectures and specific applications are taught in working groups using projects. This choice is specifically useful for groups with a high number of students (> 20) where the standard lecturing is a very efficient and powerful tool. In each project the context of the application is described, the problem is outlined, the student is challenge to solve some items in groups and the final solution is discussed using slides and simulations. Some samples of the projects are briefly cited below:

- *Synchronous generators used for mills in the copper industry (for EM subject)*: the industrial process to obtain usable copper is described in this project. Within this industrial application there are different processes involving knowledge of mechanical, chemical, electrical and electronics engineering. The project focuses on the mill used to break the material up using gravity and iron balls in a mill which is driven by a 20 MW synchronous motor. The students are challenged to solve some questions, both qualitative and qualitative. The whole drive is simulated in Matlab/Simulink to confirm the solution of the questions.

Fig. 2. Synchronous motor drive in SAG mills at copper industry.

- *Power factor correction of a pottery industry (for TC subject):* this project describes a pottery industry, indicating the different electrical elements present in the industry, such as the compressors, the monostratum ovens, the motors for the serigraphy process, the offices, etc. The rated power and power factor of each element in the industry is provided and the student is challenged to solve some questions in the proposed scenario. The questions involve not only quantitative items but also some open questions (*How can you improve…?, what would happen if…?*).

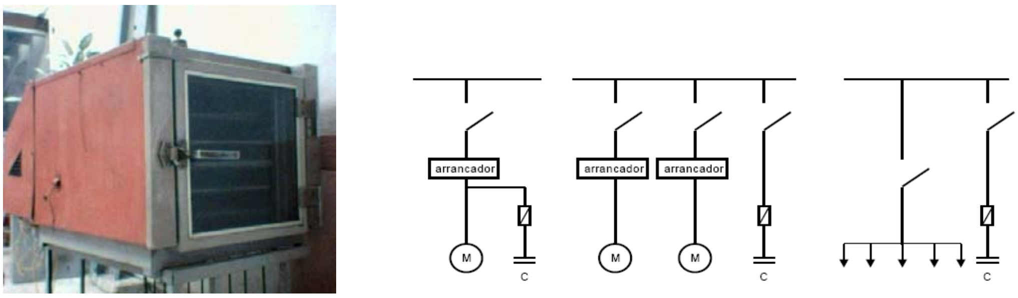

Fig. 3. Oven used in the pottery industry and scheme of the power factor correction.

- *Calculus of cable sections and protections in a low power electrical installation (for ID subject)*: a standard factory building is considered describing the different elements (lathes, pumps, illumination). The students are provided with the Spanish regulations for low voltage electrical installations and with commercial catalogues of cables and protections. Learners are challenged to do several tasks using the proposed interactive methodology.

3.2. Cross projects.

In addition to the development of individual projects for each subject, the Electrical Engineering Department at the University of Málaga is developing cross projects that involve several subjects. The cross projects select topics that involve knowledge from different fields. Examples of such topics are the electrical vehicles (EVs) or wind energy conversion systems (WECS). These projects are created with two different parts:

- ✓ A common root describing the state of the art of the topic. This part describes the general situation of the application, the technical content associated and includes simplified equations of the system. This common part of the project includes detailed information that can be out of the aims of a particular subject but serves as general technical information for student to increase his motivation and look beyond the limits of a particular subject. For the sake of example if the project is related to electrical and hybrids vehicles (HEVs), the common part includes the electrical system of the vehicle, the next generation vehicles, the types of motors of commercial vehicles (e.g. permanent magnet brushless drive for Toyota Prius), the mechanical equations of a vehicle, etc. If the project is related to WECS, the common part describes the importance and current state of the WECS, the wind energy penetration in the electrical system of different countries, the legal regulation of the WECS, the different types of WECS, the equations of the wind power as a function of the wind speed and the pitch angle, etc.

Fig. 4. Next generation vehicles: Twizy Z.E y Fluence Z.E.

- ✓ A specific part involving the technical content of a particular subject. After the common part it is necessary to show information related to each particular subject to challenge the student to solve some problems using what has been taught in class. This is the moment when each project is divided in different branches associated to each subject. For example, if the project is related to WECS, the application can serve to study AC circuits in Electrical Circuits (EC), induction generators in Electrical Machines (EM), protections in Electrical Design (ED) or field oriented control in Electrical Drives (EDR). On the other hand, the electrical vehicles application can serve to study DC circuits in (EC), DC machines in (EM), cable selection in ED and DC control in EDR. Each branch of the project provides different data to the student, showing motor parameters for EM subject, cable information for ED, equivalent circuits of the machine and network for EC or controller parameters for EDR.

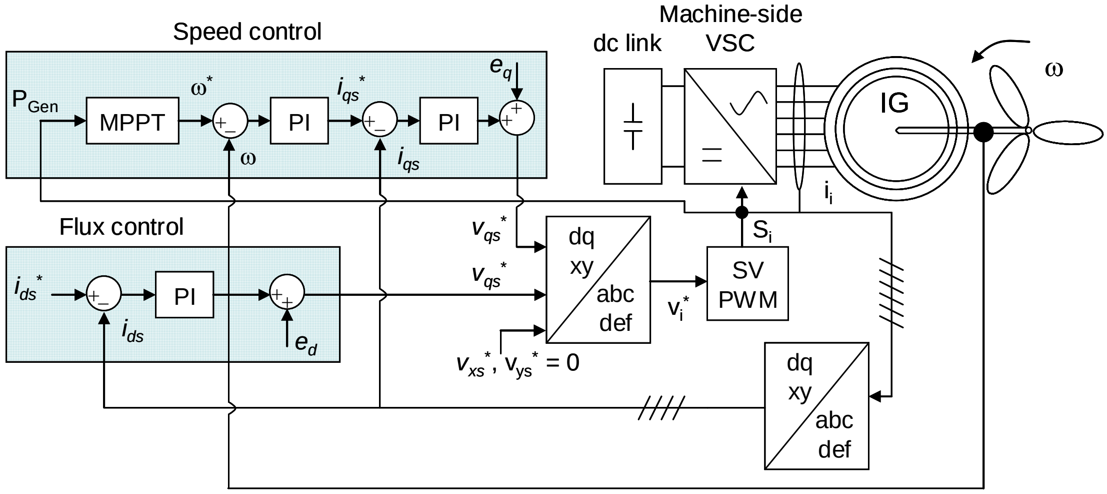

Fig. 5. Field oriented control of an induction generator for a WECS application.

The cross projects provides coherence to the curriculum associated to the electrical engineering topics and helps the student to understand that real problems are usually multidisciplinary. Furthermore, the student realizes that each subject is useful to solve different problems. A student can solve AC circuits of a WECS in (EC), he will understand the equivalent circuit of the WECS generator in (EM), he will learn to select protections in (ED) and he will understand how to dynamically control the generator to extract the maximum power from the wind in (EDR). In this way the same application crosses different subjects of different degree courses providing a framework to understand the evolution of the student learning.

4. An interactive methodology

If the projects are presented in a standard lecture with traditional methodology, it would be useful to connect the technical content with real-world applications but it would still remain being a teacher-centred teaching, not promoting transverse competences. The projects are used with an interactive methodology using the following steps:

- ✓ *Presentation of the project:* at this stage the project presents a certain scenario, an industrial context where the knowledge involved in the subject is going to be tested. The presentation of the scenario is done in a similar way to a standard lecture, but emphasizing the connection with the industrial problems.
- ✓ *Challenge the students to solve some questions:* after the presentation of the scenario, the project includes specific questions for each subject to challenge the student and test their understanding of the main concepts of the chapter.
- ✓ *Brainstorming and collection of ideas:* as soon as the project is presented, the students start to work in the project questions and the teacher is no longer the centre of the class. The responsibility of the teacher is just to supervise and guide the groups. The groups must have a single solution, and so they are encouraged to discuss and find a consensus about the right solution.

- ✓ *Simulation, visualization, solution:* Once the groups have given their answer to the questions, the project is solved using chalk-and-board (for math) and simulation tools (to visualize the solution).
- ✓ *Discussion and theoretical explanation:* The different solutions are discussed and the theoretical explanation is emphasized, finally connecting the theory with the solution of a specific and real-world application.

The proposed methodology is design for a synchronous application within the lecture time, but the projects can also be used asynchronously as homework for the students. Both methodologies can be also mixed, solving some projects during the class time and leaving other projects for the students homework. Asynchronous implementation can also be very useful within the new methodologies within the European higher education area (EHEA).

5. Results

The proposed methodology, using individual projects, was firstly tested on the 2008/2009 course at the School of Engineering in the University of Málaga. A general test (table 1) already implemented in [14] was used to evaluate the students' satisfaction with the proposed methodology. The test consists of 26 questions that serve to evaluate several dimensions of the teaching-learning process. The score is set between 1 and 7, where 1 means "strongly disagree", 7 means "strongly agree" and 4 is "neutral". The test includes some redundancy to properly check the students' response. The dimensions that group all the students' answers are motivation, understanding, means and interactivity. The students' feedback can be observed in table 2, obtaining a mean value of all answers equal to 4.22 which is above the middle of the scale (set in 3.5). The questions suggest that students find they are learning a useful content with adequate material but still find some problems to participate in class. In order to properly analyze the students' feedback, the items of the questionnaire are organized grouping the questions within several dimensions that are shown in table 3. Results show that the material is adequate that the students feel they are improving their understanding, having a positive value of the teaching activity. Motivation and interactivity are close to neutral score, which means that students still need a further challenge to increased motivation and promote participation. Even though the participation is not the higher scored dimension, it must be noted that interactivity is a dimension with a low initial value in the pre-implementation stage, so the results must be considered as an incremental improvement. In the next step the cross projects will be implemented aiming at improving motivation and multidisciplinary knowledge.

6. Conclusions

The paper describes a methodology that combines traditional teaching with an interactive project based approach. The teaching proposal is shown describing some of the projects used in several subjects within the electrical engineering area. Two types of projects are described: individual projects for each subject and cross projects that include multidisciplinary content within the electrical engineering area. The innovation includes projects that are close to real-life industrial problems implemented with an interactive methodology that improves cross competences. Results of individual projects show a good acceptance although the motivation can be further improved using cross projects.

Table 1. Questoionnaire for students' feedback.

C1	The content is easy to understand.
C2	The material used for the explanation is clear enough.
C3	The material provided with the chapter is useful to understand the main concepts.
C4	The understanding level alter attending the class is adequate.
C5	Real examples are shown during the class.
C6	The tools and means used for the lecturing are adequate for the explanation.
C7	The content fulfils the learner formative needs.
C8	Learning performance is improved due to the variety of equipments and devices used during the required work
C9	The learner can solve the difficulties that appear during the explanation.
C10	The teachers are approachable and willing to solve the doubts that may arise.
C11	The available tools and resources ease the detection and solution of the existing doubts.
C12	The content is easy to follow
C13	The content level is adapted to the students' formative level
C14	The classroom atmosphere is friendly.
C15	Time supplied for lecturing is appropriate
C16	The motivation infused by the instructors to learn the content is high
C17	I enjoy during the lecturing
C18	Attending the course is a motivating activity for me.
C19	I feel part of group during the classroom explanation.
C20	I chase the opportunities to participate during the class.
C21	I usually take the initiative to solve the doubts that arise in the class.
C22	The teachers promote the participation in the class.
C23	I think attending the lectures improves my understanding.
C24	Value in which degree attending the classes is a positive activity where you have learned something valuable.
C25	Value globally the means used during the class.
C26	Globally value the didactic means used during the class.

Table 2. Mean value of the questionnaire response.

Q1	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*	*Q7*
3.91	4.16	4.36	4.11	4.84	4.84	4.82
Q8	***Q9***	***Q10***	***Q11***	***Q12***	***Q13***	***Q14***
4.28	4.26	5.3	4.24	3.7	4.37	4.66
Q15	***Q16***	***Q17***	***Q18***	***Q19***	***Q20***	***Q21***
4.39	3.88	3.44	3.65	3.86	3.37	3.20
Q22	***Q23***	***Q24***	***Q25***	***Q26***		
4.04	5.7	5.57	4.35	4.46		

Table 3. Dimensions from questionnaire.

Motivation	Interaction	Understanding	Means
4.1	4.1	4.5	4.4

Referencias

[1] E. Tovar, M. Castro. *Building Common Spaces in Engineering Education: A Review From ICECE05. IEEE Trans. on Education*. Nº 50(1), 79-84 (2007).

[2] M. Edwards, L.M. Sanchez-Ruiz, C. Sanchez-Diaz. *Achieving Competence-Based Curriculum in Engineering Education in Spain. Proceedings of the IEEE*. Nº 97(10), 1727-1736 (2009).

[3] C. Savander-Ranne, O. Lunden, S. Kolari. *An Alternative Teaching Method for Electrical Engineering Courses. IEEE Trans. on Education*. Nº 51(4), 423-431 (2008).

[4] M. Duran, S. Gallardo, S. Toral, M. R. M. Torres, and F. Barrero. *A learning methodology using Matlab/Simulink for undergraduated electrical engineering courses attending to learner satisfaction outcomes. Int. Journal of Tech. and Design Ed.,* Nº 17(1), 55-73 (2007).

[5] S. L. Toral, F. Barrero, M.R. Martinez-Torres, S. Gallardo, M.J. Duran. *Modeling Learner Satisfaction in an Electronic Instrumentation and Measurement Course Using Structural Equation Models. IEEE Trans. on Education*. Nº 52(1), 190-199 (2009).

[6] S. Gallardo, F. Barrero, M.R. Martinez-Torres, S. L. Toral, M.J. Duran. *Addressing Learner Satisfaction Outcomes in Electronic Instrumentation and Measurement Laboratory Course Organization. IEEE Trans. on Education*. Nº 50(2), 129-136 (2007).

[7] E.D. Wagner, B.L. McCombs. *Learner-centered psychological principles in practice: designs for distance education. Educational Technology*. Nº 35(2), 32-35 (1995).

[8] P.M. Rowell. *Perspectives on pedagogy in teacher education: the case of Namibia. International Journal Educational Development*. Nº 15(1), 3-13 (1995).

[9] M. O'Sullivan. *The reconceptualisation of learner-centered approaches: a Namibian case study. International Journal Educational Development*. Nº 124, 585-602 (2004).

[10] B.P. Butz, M. Duarte, S.M. Miller. *An intelligent tutoring system for circuit analysis. IEEE Trans. on Education*. Nº 49(2), 216-223 (2006).

[11] Commision of the European Communities. *Proposal for a recommendation of the European parliament and of the council on key competences for lifelong learning*. Brussels, 10.11.2005, COM(2005) 548 final.

[12] A. Haddoun, M. El Hachemi Benbouzid, D. Diallo, R. Abdessemed, J. Ghouili, K. Srairi. *Modeling, Analysis, and Neural Network Control of an EV Electrical Differential. IEEE Trans. on Ind. Electron.*. Nº 55(6), 2286-2294 (2008).

[13] M. Alfassi. *Effects of a learner-centred environment on the academic competence and motivation of students at risk. Learn. Environ. Res.,*. Nº 7,1-22 (2004).

[14] M.J. Duran, A. Trigo, S. Ceballos, J.L. Martinez. *An integrated teaching methodology for undergraduate level courses. In Proc. of ICECE05, Madrid,* (2005).

[15] S. Gallardo, F. Barrero, S.L. Toral, M.J. Duran. *eDSPlab: A remote-accessed instrumentation laboratory for digital signal processors training based on the Internet. In Proc. of IEEE IECON06*, 4656-4661, Paris (2006).

[16] L. Gomes, S. Bogosyan. *Current Trends in Remote Laboratories. IEEE Trans. on Ind. Electron.* Forthcoming, (2009).
[17] A. Martinez-Mones, E. Gomez-Sanchez, Y.A. Dimitriadis, I.M. Jorrin-Abellan, B. Rubia-Avi, G. Vega-Gorgojo. *Multiple Case Studies to Enhance Project-Based Learning in a Computer Architecture Course. IEEE Trans. on Education*. Nº 48(3), 482-489 (2005).
[18] E. Messe. *Project-oriented adjustable speed motor drive course for undergraduate curricula. IEEE Trans. on Education*. Nº 49(2), 236-246 (2006).
[19] W. Daems, B. De Smedt, P. Vanassche, G. Gielen, W. Sansen, H. De Man. *PeopleMover: an example of interdisciplinary project-based education in electrical engineering. IEEE Trans. on Education*. Nº 46(1), 157-167 (2003).
[20] D.D.V. Bhanderi, M. Bisgaard, L. Alminde, J.D. Nielsen. *A danish perspective on problem based learning in space education. IEEE Aerospace and Electronic Systems Magazine*. Nº 21(7), 19-22 (2006).