Digital Learning Object Production in Engineering Courses

S. Blanc, J.V. Benlloch-Dualde

***Title*— Digital Learning Object Production in Engineering Courses.**

***Abstract*— This paper presents an innovative-project research on promoting self-learning in Engineering university courses. The work is focused on students' homework, which consists in producing Learning Objects. The digital objects are self-contained and reusable within the course framework according to a suitable work plan and supported by digital tools. Additionally, in order to help the student on the achievement of curricula competences by producing these objects, they are also available to the whole group in the form of a digital collection of self-study material adapted to the group's characteristics .**

This paper describes a case of study, analyses students' perception of the activity, and quantifies the success of the experience.

***Index Terms*—Engineering, Digital Learning Objects, Self-centered Learning, Student Activities**

I. Introduction

THE convergence process in the European Higher Education Area has promoted a quality system that boosts active and student-centered learning. These premises have involved changes in learning methodologies of many university courses, as it has been the case at the School of Computer Engineering in Valencia, Spain.

The ECTS credits system [1] defines the importance of student activity both inside classroom spaces and beyond. Formative feedback can make this activity really effective, specially supported by an active methodology focused on student-centered learning [2].

Formative feedback has been addressed in several studies focused on fostering student activities such as in [3][4][5][6][7]. However, face-to-face activities, done in the classroom, are tackled with difficulty in large students groups. For example, core university courses in the School of Computer Engineering, at the Universitat Politècnica de València, in Spain, have regular groups with up to 50 students to be managed by a sole teacher. Thus, some alternative should be implemented.

This paper deals with an active learning strategy based on the digital production of Learning Objects (LOs) carried out by students along the course to both promote self-study and enhance learning.

Learning objects are digital compositions typically made by teachers or experts as small, self-contained and re-usable units of learning. However, the action of creating a LO is a powerful means of enhancing the learning cognitive human process, and thus, it is potentially an interesting activity to be carried out by students who will produce these small pieces of knowledge.

The creation of such objects has the additional advantage of fostering collaborative knowledge construction because any object serves to the whole group as learning material as soon as it is already produced and validated.

Obviously, when production is carried out by students instead of experts, it needs to be supervised by the teacher, reporting written details focused on both enhancing feedback and improving the quality of compositions. This paper presents an experience on LOs production in engineering courses at the School of Computer Engineering at the Universitat Politècnica de València. The experience worked on practical aspects such as the shape of LOs or how LOs are shared inside the group throughout a digital tool.

This paper is organized as follows. Section II gives a brief related work on learning objects. Section III describes the framework, methodology and objectives of this project. Section IV gives a practical approach. Section V describes the basic digital repository rules. Section VI presents our students' opinion and finally, section VII shows an example of the effectiveness of this activity in students' learning enhancement. Section VIII concludes the paper.

II. Related Work

Learning Objects are defined by the "Learning Technology Standards Committee" [8] as digital, self-contained and reusable elements. However, the standard definition is extremely broad, and so are the enumerated types of learning objects. There exists few works about the use of learning objects created by students. For example, an experience was carried out in secondary studies within the SCY project (Science Created by You) [9]. This work identifies 8 types of learning objects and 53 activities. Besides, the work sets 13 scenarios to define the creation process.

Another example was given in [10] in 2008 by C.L. Abad. However, the main objective of this experience was a peer-review assessment and LOs were not reused during the course. This research made use of existing taxonomies to classify the LO, such as the ones from Redeker (2003) [11], OSEL (2006) [12] or Wiley (2000) [13]. The last one reduces the number of object types to 5 within 5 difficulty levels.

D. A. Wiley presented in 2000 a study about LOs which includes a definition coherent with the standard. LOs are

S. Blanc is with the Universitat Politècnica de València (Technical University of Valencia), E.T.S.I.INF, camino de vera s/n, 46021, Valencia, Spain (corresponding author e-mail: sablacla@disca.upv.es).

J. V. Benlloch-Dualde is with the Universitat Politècnica de València (Technical University of Valencia). (e-mail: jbenlloc@disca.upv.es).

defined as any digital resource that can be reused to support learning. However, because in our case the production is going to be done by students, and reused by students too, it is necessary to go more deeply into the objectives of the activity and its practical approach.

III. Project Description

A. Framework

In the School of Computer Engineering, some core subjects have a large number of students – more than 300 – divided into groups up to 50 students per teacher. This is the case of computer technology or computer networks courses in the School of Computer Engineering.

The syllabus of both subjects has been defined according to national and international recommendations [14]. In particular, the main sources have been the ACM/IEEE curricula recommendations, as well as the Computer Engineering Degree Program White Paper of the National Agency for Quality Assessment and Accreditation. The computer technology course is included into the field of computer engineering in the ACM/IEEE computing curricula, and matches the non-computing topic of electronics because it is focused on semiconductor devices and logic families. The computer networks course follows the ISO levels defined to open systems interconnections (OSI).

The large number of students registered in these core courses increases diversity of basic students' learning skills. Thus, face-to-face classroom activities consume too much time when feedback is given orally and in-situ. Individual self-study tasks complemented by written feedback will deal with such diversity besides guiding students in their work planning more effectively [15][16].

Moreover, according to the current European ECTS system, university courses recognize credits of self-study activities that have been defined as 6 hours per week to both computer technology and computer networks courses.

Thus, in the 2011-2012 academic year, the faculty of the former courses launched an innovation project in education (PIME) focused on self-study learning activities on engineering courses at the university. The experience began one year before, in 2010-2011, working on a practical approach in the production of LOs by students.

B. Methodology

Methodologies referred to as active are focused on the student, whose participation in their learning promotes meaningful and deep learning for understanding and for research [1]. The teaching methods that foster student participation also demand better quality and quantity of the personal work he/she carried out both in the classroom and beyond.

Among the activities that students might work outside the classroom, this project focuses on cooperative production of LOs. Producing a LO trains the student in the following capacities: abstraction, analysis, synthesis, expression, communication of knowledge and application. Moreover, the activity can be tailored in such a way that students receive appropriate feedback about their work, allowing them to improve the quality of their compositions.

The work done by both students and teacher affects the whole group positively because the LOs are offered as course learning material, in the form of a digital collection of small compositions that comprises a complete didactic unit.

Having this objective in mind, teachers need some flexibility to assign the LOs. Each student should work on one or several LOs along the course according to his/her needs. The aim is to provide students with information about his/her progress. Moreover, the effort made by the teacher with one student should be of benefit to the rest of the group. Presenting the final result or outcome of the activity, the teacher can avoid repeating the same corrective action on a particular issue too many times.

Students enjoy the usage of this "fresh" material and adapted to the specific course in which it is produced. Furthermore, students can also be rewarded by this work, which fosters student effort.

However, in order to implement an effective cooperative production it is necessary to support the activity through an appropriate digital tool. The produced objects should be available for the entire group in a short period of time. This availability supports the reusability principle. The objects are reusable in learning although they can be also employed as models for producing new objects. When a student starts working in an unfamiliar task, examples are always welcome. Thus, the deadlines for the faculty to browse and review tasks are shortened too, in order to upload objects as soon as they become ready.

This fast accessibility cannot be implemented without a digital suitable tool, whether a general purpose tool or a specifically-made one.

Finally, the calendar for the LO production is also very important within the activity working plan. To make possible the use of these objects as soon as possible, three issues are necessary in the course schedule:

1) *Students need enough time to produce the objects taking into account the whole workload in the semester.* This premise implies coordination actions among courses.
2) *Object supervision and feedback is given during the object production, as soon as possible.* Teachers must avoid a late feedback.
3) *Objects should be available to the whole group before any assessment activity related to competences worked within those objects.*

In summary, the project's objectives are the following:

1) To be student-centered, promoting a committed student's attitude and an individual formative feedback.
2) To support scaffolding written feedback and student's progression tracking.
3) To supply qualitative evidences about the effectiveness on learning achievement.
4) To help and guide students on workload and effort distribution.
5) To work on transversal subject competences.

IV. A Practical Approach

LO are small pieces of knowledge that can be combined to create a digital collection.

Objects are produced by students alone or in small groups. However, to produce a collection, some homogeneity is expected. Thus, there exist several issues that should be specified, such as how to distribute the work among students and what any object should contain.

Work distribution can be done by assigning to several students the same concept or skill to work on. In this way, when a student uses these objects in her/his self-study she/he could select those objects which are more adapted to her/his learning style. However, repeating assignations is not necessary.

Secondly, a learning object can be considered as a combination of knowledge comprehension and practical application. Thus, learning objects are defined as digital compositions containing two parts: one part to present the knowledge and another part where such knowledge is applied.

Examples of knowledge applications for engineers are:

1) *Problem-based learning activities.* These activities are frequently proposed in engineering courses to train deductive skills and applicative abilities [17][18][19][20]. To favor the underlying cognitive process to the resolution of engineering problems, objects can include a practical application of knowledge in the form of outlining a problem and resolving it step-by-step. Moreover, transversal competences such as originality and creativity can also be put into practice. For example, home-made videos can be incorporated as a user-friendly resource.

2) *Model-based learning activities.* For example, computer programs, applets, computational functions, algorithms, simulations or prototypes.

Figures 1 to 3 show several examples of applets produced by students in 2011 and 2012. Applets are an interesting self-study resource to both the student who produces it and the student who uses it. The production virtualizes the cognitive learning process while the use of the object is a very effective e-learning tool. Each applet permits the introduction of input values and their processing. Results can be shown in two formats, numerical or graphical.

LOs are produced by students and used by students in a cooperative construction of knowledge.

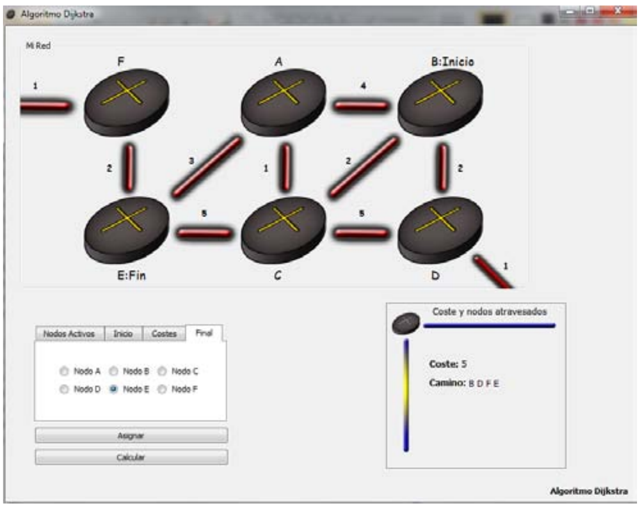


Figure 1. Java applet "Dijkstra algorithm" Computer Networks 2011-12

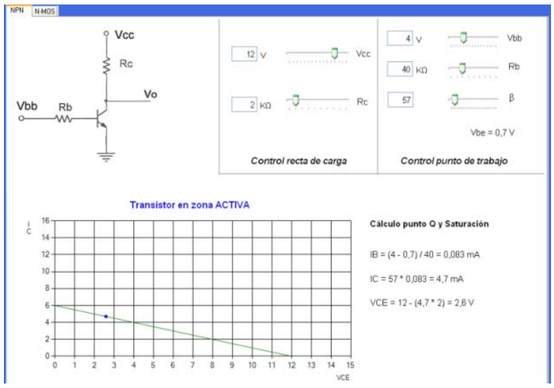


Figura 2. Java applet "BJT" Computer Technology 2010-11

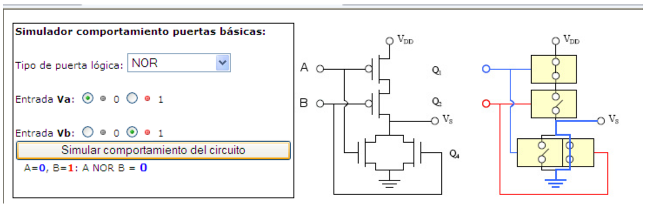


Figure 3. Java applet "CMOS" Computer Technology 2010-11

V. Digital Repositories

Students usually enjoy their time at the university. However, many of these students have difficulties at the beginning. There are formal studies about that question, as in [21]. Similar problems have been observed among our students in their last years. First-year uncertainty is softened when students can compare their individual progression to that of the general group. However, classroom spaces are not always effective at showing this group progression.

A digital repository, accessible by every student enrolled into the course, to share their works and to promote positive criteria and enhancement is inherently more effective.

However, the effectiveness strongly depends on the teacher management. The tool shown in Figure 4 was introduced during the 2011-12 academic year. This tool was specifically implemented during the project.

Many universities offer digital repositories designed to support digital communication between teacher and student. However, the cooperative creation of learning material by students needs flexible tools to support student uploading with supervision in order to guarantee quality and correctness. Instructors should take care of the accuracy of the uploaded objects. Thus, flexible and friendly digital tools are required to face this new teacher's challenge of browsing and reviewing.

In the digital repository developed during the project, two roles where identified: teacher and student. Design rules already included into the tool are:

Teachers work collaboratively and are allowed to:

- Create conceptual units
- Define groups of students
- Insert new users
- Validate uploaded objects and made them visible to students

- Remove uploaded and non-validated objects
- Allow resubmission

Students are allowed to:

- Visualize and download validated object
- Upload new objects linked with a conceptual unit
- Resubmit an object
- Remove non-validated objects (only visible by the owner)
- Give their opinion about objects usability

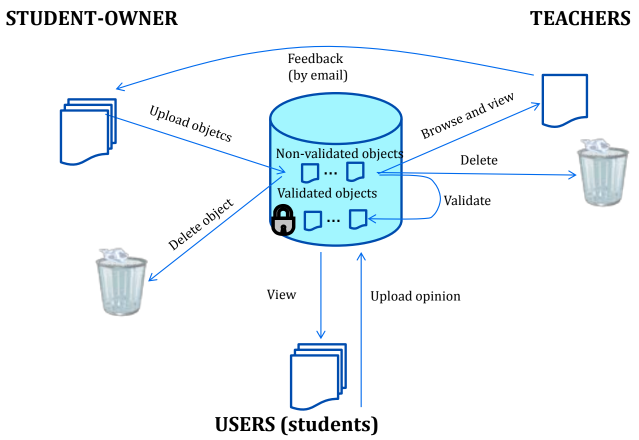


Figure 4. Data Base usage

A new object uploaded by a student is visible only to both teachers and the owner (i.e. the student who uploaded the object). Any teacher in the data base can validate the object. Before validation, the owner can remove/resubmit the object but it is forbidden after its validation. Figure 4 shows an example of the digital repository data base.

Additional features are under development such as forking, internal emails and digital ink linked to assessment tasks. Moreover, metadata definition is also in improvement in order to index these LOs in public data bases.

VI. Student's Perspective

At the end of the second semester of the 2011-2012 year, students enrolled in the computer networks course were questioned about the project to determine relevant aspects such as the interest of students in the produced material or the benefits of creating learning objects in their learning process.

The survey was answered by 41 students out of 47 who had participated in the experience along the semester.

A. *Examples*

Questions about the use of the material in self-learning were divided into two sub-items. Firstly, the use of these materials to produce their own assigned work. Secondly, the survey included questions about the use of these materials to prepare written assessment tests (there were two assessment tests along the semester).

The survey included the following question: "*Did you use learning objects created by your classmates to create your own learning object?*":

37% agreed and 68% also answered affirmatively to the question "*Would you like to have more examples of learning objects produced by other students to create your own?*":

Generally speaking, any task done individually by our students out of classroom implies doubts and anxiety about how to face it. Students feel more confident when they can view examples of similar tasks, and in many cases they construct their own production starting from these examples.

However, the use of material to produce material has a requirement: tool filtering options are necessary to avoid bad copies, incoherencies or non-quality production.

B. *Self-study and autonomy*

On the other hand, the questionnaire includes direct questions about the use of the learning objects created by other students to support self-study. 68.3% recognized their use to prepare both written assessment tests. The percentage is quite significant because it is one of the actual objectives of the production.

Benefits about the production of learning objects as learning activity were also questioned. 69.2% of students considered the production very positive in reinforcement and course workload planning.

However, it is important to identify the personal intention of our students when they agree on the production. The survey included the question "*How did you decide the subject of your learning object?*" with two closed answers: a) "*because I wanted to learn more about the subject*" and b)"*because I am very confident with the subject and I could do a good work.*"

46.3% chose a) while 36.6% chose b). 17.1% preferred not to answer this question. To learn more about a subject is close to teachers' intention of promoting homework. However, university students frequently look for good scores rather than the learning achievement. However, how can teachers make a good allocation of tasks among students? It is necessary to assume that any allocation will have a relevant contribution to the group in the cooperative process of production and that it must be the student herself/himself who decides about what and how she/he wants to learn. The coexistence of an individual evaluation by learning object production and a general evaluation by written assessment tests will assure that any student who passes the course will have achieved those minimum expected competences defined in the course curriculum.

C. *Feedback*

From the formative point of view, the most important benefit in producing learning objects – under the methodology above described – is the feedback obtained by the student about her/his progress.

In LO production and sharing, feedback is given by teachers but also by the whole group. 49% of students recognized the necessity of receiving feedback from the teacher to improve their compositions. However, 61% preferred to get some inputs from their colleagues before asking the teacher. Again, this percentage reveals the students' insecurity and a lack of practice on receiving formative feedback. That suggests a lack of maturity. In fact, students tend to upload the first version of their object as late as possible . This makes it impossible for the teacher to give weekly review and feedback and to avoid workload peaks –which is unapproachable with large groups. Thus, deadlines and milestones should be carefully designed depending on our students' profile.

D. *Real accesses to the production*

Finally, the survey has been complemented with additional data about accesses and downloads of material via web. The digital repository includes counters useful to statistic purposes.

For example, in a sample of 80 LOs there were registered 1407 accesses done by 45 identified students divided into 968 accesses to objects with problem-based activities and 439 accesses to objects with model-based activities.

VII. Results

Quantitative results were also obtained from the students' sample of the previous section. The computer networks course is a 30-weeks course. Students are divided into 6 groups of 50 students each. For 15 weeks, every group carried out similar activities and assessment. In the last 15 weeks, one group was involved into the LOs experience.

Figures 5 and 6 compare average results between the experimental group and the five not involved in the experience. Figures depict the percentage of students that achieve a mark, in a 10-point scale, lower than 5, between 5 and 7, between 7 and 9 or higher than 9.

Figure 5 compares the marks of the experimental group during the initial 15 weeks, when the 6 groups carried out similar activities, while Figure 6 depicts the same comparison during the last 15 weeks.

The experimental group has worse results in all the intervals. For instance, in the lowest interval the percentage of the experimental group is a 20% higher than in the other groups. Generally speaking, the experimental group found more difficulties in getting good marks than their course-mates.

However, during the last 15 weeks, while they were working on LO production, this tendency was inverted. Figure 6 shows a similar number of students having less than 5 points. But it is quite interesting that the experimental group registered better results in marks between 5 and 9 than their course-mates. It was very positive.

Firstly, the experimental group undergoes an important enhancement in their learning achievements comparing both course parts (initial 15 weeks and last 15 weeks). Secondly, this enhancement is more significant when we take into account that the second part of the course is based on knowledge and skills worked on during the first part, where 20% of the students didn't achieve the minimum expected to begin with the second part. Consequently, the effort demanded of students enrolled in the experience is high because they must recover from their lacks in the first part and overcome the second part all the same time.

VIII. Conclusions

This work describes a proposal on the production of learning objects by students in engineering courses. The proposal has been implemented in first and second year university courses, having large groups of students.

In summary, the implementation of the proposal was feasible. In relation to teachers, it increases their effort along the course, but it should not be considered an untenable overload. Digital tools are essential to relieve teachers' work but also because the LOs must be available on-line as soon as possible to the whole group to serve in a cooperative construction of learning.

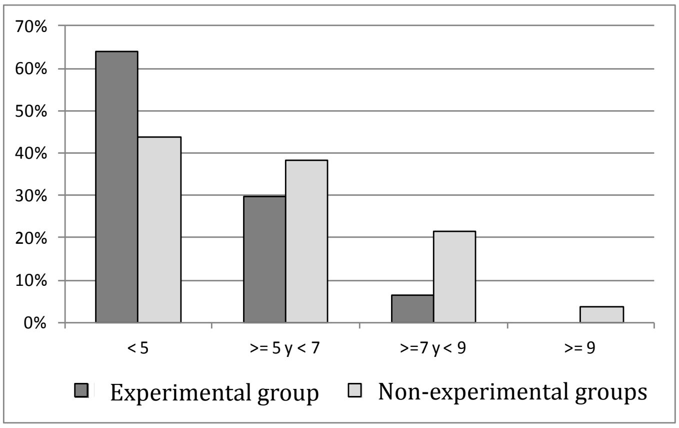


Figure 5. 15 initial course weeks – Marks comparative

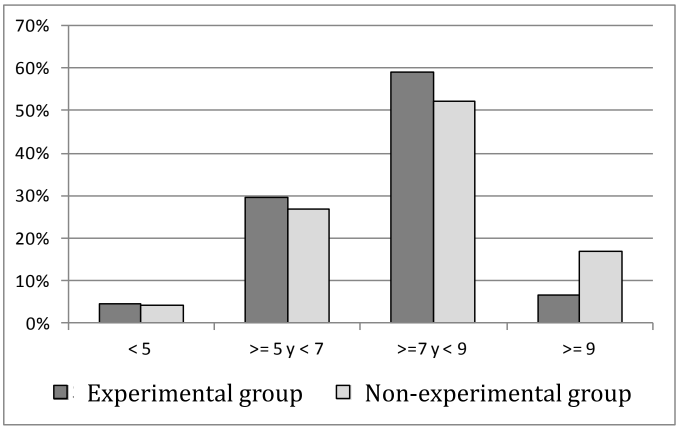


Figure 6. 15 last course weeks – Marks comparative

Benefits obtained by students are based on individual feedback and as guide to distribute students' effort effectively along the course. Moreover, the proposal also deals with the students' lack of maturity in learning skills.

The opinion reported by our students supports the continuity of the experience. 69.2% of students considered the production as a very positive task. The reticence observed among the rest could be overcome in future years by improving additional aspects, such as the inclusion of digital guidance throughout the creative process or digital ink tools to facilitate feedback actions.

Acknowledgements

This work has been partially funded by the School of Computer Engineering (E.T.S de Ingeniería Informática) at the Universitat Politècnica de València.

References

[1] ECTS system. ECTS: European Credit Transfer and Accumulation System, available in web.

[2] A. Fernández-Marc. Metodologías Activas para la Formación en Competencias, Instituto de Ciencias de la Educación, Universidad Politécnica de Valencia, Educatio siglo XXI 24, pp. 35 – 56, 2006.

[3] X. C. Pardo, M. J. Martín, J. Sanjurjo, C. V. Regueiro. Teaching Digital Systems in the Context of the New European Higher Education Area: A Practical Experience. IEEE T. on Education 52(4), pp. 513–523, 2009.

[4] J. García, A. Hernández. Active Methodologies in a Queueing System Course for Telecommunication Engineering Studies. IEEE T. on Education 53(3), pp. 405–412, 2010.

[5] J.V. Benlloch-Dualde, F. Buendía, J.C. Cano. On the Design of Interactive Classroom Environments based on the Tablet PC

Technology. 40th ASEE/IEEE Frontiers in Education Conference-Celebrating 40 Years of Innovation, 2010.

[6] L.de la Fuente-Valentín, A. Pardo, C.Delgado Kloos. Addressing drop-out and sustained effort issues with large practical groups using an automated delivery and assessment system. Computers & Education 61, eepp. 33–42, 2013.

[7] F. J. García, M. N. Moreno. Software Modeling Teaching in a First Software Engineering Course. A Workshop-Based Approach. IEEE Transactions on Education, 47(2), 180-187, 2004

[8] IEEE Standard for Learning Object Metadata. IEEE Standard 1484.12.1, Institute of Electrical and Electronics Engineers, New York, 2002. (draft) URL last accessed on 2007-04.

[9] T. de Jong et al. Learning by creating and exchanging objects: the SCY experience. British Journal of Educational Technology 41(6), pp 909-921, 2010.

[10] C. L. Abad. Learning Through Creating Learning Objects, ITiCSE 2008 Madrid, Spain.

[11] G. H. Redeke. An Educational Taxonomy for Learning Objects, IEEE International Conference on Advanced Learning Technologies (ICALT 2003), página 250, 2003.

[12] V. N. Convertini, D. Albanese, A. Marengo, V. Marengo, M. Scalera. The OSEL Taxonomy for The Classification of Learning Objects. Interdisciplinary Journal of Knowledge and Learning Objects 2, pp 125–138, 2006.

[13] D. A. Wiley. Connecting learning objects to instructional design theory: A definition, a metaphor, and a taxonomy. The Instructional Use of Learning Objects: Online Version. 2000. http://reusability.org/read/chapters/wiley.doc, accedido en 2007.

[14] Grado de Ingeniería Informática. Plan de estudios E.T.S. Ingeniería Informática, página oficial: http://gradoinf.webs.upv.es.

[15] D.J. Nicol, D. Macfarlane-Dick. Formative Assessment and Self-Regulated Learning: a model and seven principles of good feedback practice. Studies in Higher Education 31(2), pp 199-218, 2006.

[16] V.J. Shute. Focus on Formative Feedback, Educational Testing Service. March 2007. ETS Research Report, RR-07-11, pp. 1-47, Princeton, NJ.

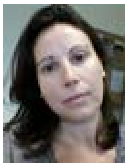
[17] C. E. Hmelo-Silver. Problem Based Learning: What and How Do Students Learn? Educational Psychology Review 16(3), pp. 235-266, 2004.

[18] B. J. Duch, S. E. Crah, D. E. Allen. The Power of Problem-Based Learning: A Practical How To for Teaching Undergraduate Courses in any Discipline. (1st ed.) Sterling, VA: Stylus Pub 2001.

[19] E. Montero, M.J. González. Student Engagement in a Structured PBA to Learning: A first-year electronic engineering study module on heat transfer. IEEE T. of Education 52(2), 2009.

[20] C. E. Hmelo-Silver, R. G. Duncan, C. A. Chinn. Scaffolding and Achievement in Problem Based and Inquiry Learning: A Responce to Kirschner, Sweller and Clark (2006). Educational Psycologist, 42(2), pp.99-107, 2007.

[21] K.L. Krause, R. Hartley, R. James and C. McInnis. The First Year Experience in Australian Universities: Findings from a Decade of National Studies. Final report, Enero 2005.



S. Blanc. She was born in Valencia (Spain). She earned a MSc. in Computer Engineering from the Universitat Politècnica de València in 1998 and a PhD in Computer Architecture and Technology from the same university in 2004. She has been a Teacher at the Escuela Tecnica Superior de Ingeniería Informática (Computer Engineering) in the Universidad Politécnica de Valencia since 2001 in Computer Technology, Computer Basic Science and Microcontrollers and Reconfigurable Systems. Her research interests are in the field of Fault Tolerance and Embedded Systems, with special current interest in Underwater Communications.

J.V. Benlloch-Dualde (M'09). This author became a member (M) of IEEE in 2009. He was born in Valencia (Spain) in 1962. He earned a MSc. in Physics from the Universitat de València in 1986.

Currently, he is a Senior Teacher with tenure at the Escuela Técnica Superior de Ingeniería Informática (Computer Engineering) in the Universitat Politècnica de València, where he teaches a course in Computer Technology and several elective courses about Multimedia Systems in the same center. His research interests relate to technology-enhanced learning and pen-based technologies. He earned a HP Technology for Teaching Grant Initiative, Transforming Teaching and Learning through Technology in 2008.