Innovative Learning and Teaching Methodology in Electronic Technology Area

A Case of Study in Computer Science University Degrees

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Abstract—**This paper describes an experience that has been carried out by several professors in different subjects. Our experience is framed within the First Plan in Teaching of the University of Seville. All involved subjects belong to the electronic technology area and from three Computer Science degrees. We propose to use, in a combined way, some learning techniques: cooperative learning as complement to traditional learning, role-playing technique and jigsaw technique. We have considered a base methodology but in each subject a variant of it has been accomplished. We have used several evaluation techniques, such as reciprocal evaluation, electronic portfolio and check lists. Applying our methodology helps us to detect learning problems before the term ends. Also, in tune with the framework of the European Higher Education Area (EHEA), our methology gives a boost to develop transversal competences as important as work (or study) management, empathy and understanding of other members in a workgroup, conflict resolution, capacity to make decisions as well as coordinate and communicate with other members in a workgroup and also with the professor.**

Keywords-component; Innovative education, evaluation techniques, cooperative learning, role-playing, reciprocal evaluation, electronic portfolio.

I. INTRODUCTION. BACKGROUND

The experience described in this article is part of a project granted by the University of Seville's First Self-funded Teaching Scheme. This project focuses on aspects related to the implementation of the role-playing technique combined with cooperative work. The tasks carried out under this project seek improvement in the learning process of students.

The project has been implemented in all three Computer degrees at the University of Seville:

- Engineering in Computer Science (ECS, 5 years)
- Technical Engineering in Computer Systems (TECS, 3 years)
- Technical Engineering in Computer Management (TECM, 3 years)

The experience described in this article is a summary of what was implemented during the academic year 2008 / 2009 in classroom groups listed in TABLE I. The First-year courses are all compulsory, while the third and fifth-year subjects of study are optional.

TABLE I. SUBJECTS OF STUDY INVOLVED IN THE PROJECT

Subjects of study	Degree	Year	Class-room group	Nº of studen ts	Teacher
Computer Structure and Technology II	TECM	*1º*	2	*87*	*M.C. Romero*
Computer Structure	TECS	*1º*	1, 2 and 3	*240*	*I.M. Gómez & M.P. Parra*
Computer Structure	ECS	*1º*	1 and 2	*150*	*C. Baena & M. Valencia*
Peripheral and Interfaces	TECS	*3º*	All	*120*	*F. Sivianes*
Advanced Digital Systems	ECS	*5º*	All	*20*	*M. Valencia*

The content of this paper is arranged as follows. In the next section we outline the motivations of our work. In section III we identify our main goals and, in section IV, the methodology followed for the execution of the work, which presents variations in the different subjects of study. In Section V, we discuss briefly some of the results obtained and, in section VI, we finish by stating the main conclusions.

II. MOTIVATIONS

Traditionally, expositive lectures have been the most common in university classrooms promoting, in most cases, individual student learning. With the implementation of the EHEA [4], the Technical College of Engineering and Computer Science at University of Seville joined in 2003 a pilot adaptation project, which, over time, has incorporated most of the subjects taught at the Technical College. Our department has actively participated in this pilot experience from the beginning and during subsequent courses, incorporating into their courses different ongoing evaluation mechanisms in line with the new European framework ([7], [8], [9] and [10]).

In our effort to improve student learning, during the last academic year (2007/2008) we started an isolated experience in group work and in the current academic year (2008/2009) we have implemented the project entitled "Implementation of the role-playing learning technique in groups from different computer science degrees and courses". Furthermore, in some of the groups, the role-playing technique was combined with cooperative learning activities.

In the role-playing technique or role exchange [7] students adopt a role and are encouraged to think, act and make decisions as their characters would. This technique promotes creativity, teamwork, reading and oral and written communication. This is a very versatile technique that can be applied in virtually all areas of knowledge and enables the simulation of real-life situations.

Moreover, as J. B. Cuseo noted in [3], cooperative work provides some advantages compared with traditional learning, such as:

- Promoting the active involvement of students during the learning process,
- Giving importance to the interaction of group members as a tool to increase the level of learning (group and individual),
- Reducing dropout rates in classrooms,
- Promoting critical thinking,
- Increasing student satisfaction in what they learn and how they learn it and promoting more positive attitudes towards the subject of study,
- Achieving better academic performance in science and technical areas, and
- Preparing students for the workplace.

In our project we propose to combine both techniques taking the best of each approach.

III. OBJETIVES

Our work focuses on improving the learning process of students studying subjects related to Electronic Technology within Computer Science, although what is described in this article could be applicable to any other matter. In this paper we propose its application to five subjects of study including:

- Computer Structure and Technology II (TECM), Computer Structure (TECS) and Computer Structure (ECS): all three are compulsory subjects for first year students and have very similar content. They are courses on computer design and applications –of Digital Systems in general– at RT (Register Transfer) level, and by creating a bridge between hardware and software, they develop programs at the machine-instruction level (assembly).
- Peripherals and Interfaces (TECS) is a third-year elective subject that aims to provide students with knowledge about specifications and technical literature on peripherals provided by manufacturers of equipment and programs; to solve problems with peripherals and interfaces found in an information system, application or network and to design and implement a control software or driver to control peripherals.
- Advanced Digital Systems (ECS) is a fifth-grade subject also optional that deals with the realization of digital systems with high speed and power consumption performance using advanced integration technologies and high-density programmable circuits (FPGA: Field Programmable Gate Arrays).

As mentioned before, in order to achieve this improvement in the learning process two different techniques have been jointly applied: role-playing and cooperative learning. They have not been applied exactly in the same way in all groups, as we will explain below.

On the one hand, by applying the role-playing technique we attempt to promote empathy and understanding for others, since all students perform all defined roles and are able to put themselves in their peers' shoes. Putting it into practice continuously during the academic year, students will be able to recognize, in themselves and in their peers, their capabilities, attitudes, values, and in some cases, to characterize their conduct and that of their classmates. In addition, it encourages students to accept others, resolving conflicts and developing responsible decision-making skills.

Furthermore, when combined with collaborative work, the development of abilities related to the five ingredients of cooperative learning is encourage [6]: positive interdependence, individual accountability, face to-face interaction among the peer group, interpersonal and group skills (such as coordination and communication) and group reflection.

All these abilities can be considered within the transversal skills put forth by the EHEA and its practice enables students to enter the workforce with some background in these skills.

As we will see below, in some classroom groups the ultimate goal has been for each cooperative group to develop, by the end of the teaching period, an electronic portfolio that showcases the work developed by that group during the entire

course and, moreover, it has proved a useful tool for evaluating the work of the group.

IV. METHODOLOGY

First of all, it must be noted that the activities developed for this project were proposed to students as elective tasks as part of continuous assessment. Then, at the beginning of the term, students will decide whether or not they want to perform them. At this point an immediate question arises: what do students who choose not to perform these tasks do when group sharing takes place in the classroom? In our case, that time may be used to study the subject or resolve any question that the teacher can propose.

If the student chooses to perform these activities, we ask them to make certain commitments, such as continuing with the activities throughout the semester, otherwise he or she would leave the group stranded, and attending classroom lessons, at least on the days scheduled for group sharing (they are provided with a calendar).

To carry out this project each teacher divided the subject to teach in as many sections as the different tasks programmed in the course. Obviously, the division of the subject depends on the subject syllabus and how the teacher wants to schedule each activity during the semester. In our case, although the basis of the methodology was common, each teacher applied it slightly differently in each subject, which shows that, albeit general, this methodology can be tailored in multiple cases. A detailed explanation on what has been applied in each course will be provided in the next sections.

A. Methodology basis

Students are assigned to three- or four-member base groups[1], ensuring that the number of students matches the number of roles defined. The number of roles should match the number of sections in which the teacher has decided to divide the subject syllabus for the continuous assessment. Thus, each student performs all the roles on a rotating basis and the total number of activities carried out by the group also matches that number.

Several strategies are possible for the selection of base groups. For example, in one of the strategies applied in our case students can choose a partner and the teacher is the one who arranges the entire group in pairs. In this way, the formation of groups of friends is avoided and it promotes students to strive to work with peers whom they do not know, which is a situation similar to the one they will most likely face as they enter the workplace.

Each group should do as many activities as the number of sections in which the teacher has divided the subject syllabus and each student has a different role in each task.

The activity statement of each cooperative task performed by the groups is made public through the e-learning platform (WebCT in our case) or in the classroom. It includes all the roles and their descriptions. Each group member may decide the initial role assignment.

[1] Base groups last for the entire course.

In some courses, each group should develop an electronic portfolio which will include the work of each section, both the individual work of each group member and that of the group. Portfolios are handed in upon completion of each section of a task, so that teachers can analyze learning trends and detect any anomalies, which is what teachers usually call "concept failures". Error explanations are provided to the group, not to individual students, so if it is a common error, not only will the student who made the mistake learn, but also the rest of his or her teammates.

In the prototype project each task is also divided into four parts:

- Part I: Work Planning. Each group should come to an agreement and establish a task calendar. When the activity is finished, each group should hand in a document showing the originally planned programming and the real one, with a brief analysis explaining the difference between them, either in a paper document or uploading the document to the electronic portfolio.
- Part II: Assimilation of fundamental concepts. For this part the following must be programmed:
  - Individual reading of the relevant subject outside the classroom and each group member will independently develop:
    - Student 1: a concept map relating the key concept of the relevant subject to all areas studied in this subject.
    - Student 2: ten three-choice, multiple-choice questions (a, b and c) on the appropriate topic.
    - Student 3: a glossary of the fifteen key terms of the relevant subject.
    - Student 4: A two-page (maximum) summary of the most important aspects of the topic.
  - Experts meeting to discuss the documentation produced using the puzzle technique (or jigsaw) [5].
  - Base group meeting so each student can explain his/her assignment to their classmates.
  - Homework: corrections, amendments and assignments should be included in the portfolio or paper document.
  - Submission of portfolio or paper document to the teacher.

  The idea is that students learn to solve any problems and questions proposed by the teacher on the subject to study, using the puzzle method, and that any group member understands how the concept map is constructed, is capable of solving the multiple choice questions, defines any glossary term and considers whether the summary of the subject prepared by their colleague is adequate or not.
- Part III: Practical applications of concepts. Learning to select the most important aspects of the subject, to write a statement correctly and to solve it in the most appropriate way.

TABLE II. *ROLE ASSIGNMENT*

Student	Role	Developed Skills
Student 1	PROPOSER Teacher that proposes a test statement on the relevant matter.	The ability to analyze what information is the most important of the subject taught; the ability to effectively search for information to prepare the statement; implementation of the knowledge acquired in Part II, since the statement should be feasible for the Student; self-assessment capability; and motivation to propose innovative and challenging statements.
Student 2	REVISER and EDITOR Teacher that: • reviews the proposed statement • corrects the exams • reviews exams with students once they are corrected	Critical ability, and putting into practice the knowledge acquired in Part II. The ability to assess the work done by someone else and to take responsibility for that assessment. The ability to set objective correctness criteria. Developing communication skills when justifying grades to students during the review period with the marking criteria set in advance.
Student 3 (*)	STUDENT Student tested on solving this statement in the time specified by the proposer.	The ability to cope with a problem on your own in a bounded time and the motivation to reinforce the knowledge acquired in class and the work of Part II.
Student 4 (*) (**)	STUDENT Student tested on solving this statement in the time specified by the proposer.	The ability to cope with a problem on your own in a bounded time and the motivation to reinforce the knowledge acquired in class and the work of Part II.
(*) Students 3 and 4 should resolve the problem individually. (**) When four-member groups are not feasible, the Student 4 role disappears.		

Table II shows the initial role assignment, taking turns with each activity, and the various skills that are developed for each one.

After this phase, each student must prepare the documentation for the group work associated with their role. The documentation of the entire group is included in the portfolio or in a paper document and delivered to the teacher for review.

- Part IV - Mini-conference: Learning to apply the skill of synthesis, to perform oral presentations and prepare visual documentation in the shape of a poster.

The group should prepare a poster on the practical application of Part III and give a five-minute oral presentation using the poster. The teacher in-situ will choose who will perform the presentation, thereby evaluating the whole group. When using the electronic portfolio for assessment, the poster will be included in the same electronic format.

B. Variations in the different subjects

The information related to the implementation of the project to each of the subjects involved is shown in TABLE III and TABLE IV.

TABLE III. *SUMMARY OF THE METHODOLOGY APPLIED IN ALL THE SUBJECTS INVOLVED IN THE PROJECT (I)*

Subject to study	Total no. of tasks during the course (***)	Topics addressed	Pedagogical techniques applied	Evaluation
CST2(TECM) – Group 2	4	– Analysis and Design of Digital Systems – Design of a simple computer – Semiconductor memory – Case study: the MC68000 microprocessor	– Role-playing – Cooperative Work – Puzzle Technique (jigsaw) Parts of the base project: All	Two individual partial tests, with two parts each, corresponding to the division of the syllabus, scored from 0 to 10. In addition, students can earn up to 1 extra point for the cooperative work by applying: - the self/peer evaluation using rubrics, - the concept map evaluation - the evaluation the poster oral presentation, - The portfolio evaluation. This additional point is added to the average score of the partial-test.
CS (TECS) – Group 1	3	– Analysis and Design – of Digital Systems – Design of a simple computer – Case study: the MC68000 microprocessor	Role-playing Parts of the base project: - Part III	1 extra-point maximum will be added to the final score of the partial test.
CS (TECS) – Group 2	3	– Analysis and Design of Digital Systems – Design of a simple computer – Case study: the MC68000 microprocessor	Role-playing Parts of the base project: - Part III	A total of one extra point will be added to the final score of the partial test.
CS (TECS) – Group 3	4	– Analysis and Design of Digital Systems – Design of a simple computer – Case study: the MC68000 microprocessor	Role-playing Parts of the base project: - Part III	A total of one extra point will be added to the score obtained in continuous assessment, which consists of two tests: **Test 1:** the SD-DC assignments score will be added. **Test 2:** the 68000 assignments score will be added.
CS (II) – Group 1	1	– Design of a simple computer	Role-playing Parts of the base project: – Part I – Part II – Part III	A total of two extra points will be added to the (CS) test score. This test will carry 33% weightage on the final score, so this assignment is worth 0.67 points.
CS (II) – Group 2	1	– Design of a simple computer	Role-playing Parts of the base project: – Part I – Part II – Part III	A total of two extra points will be added to the (CS) test score. This test will carry 33% weightage on the final score, so this assignment is worth 0.67 points.

TABLE IV. *SUMMARY OF THE METHODOLOGY APPLIED IN ALL THE SUBJECTS INVOLVED IN THE PROJECT (II)*

Subject to study	Total no. of tasks during the course (***)	Topics addressed	Pedagogical techniques applied	Evaluation
PI	3	– Characterization of peripherals and interfaces – Starting the development environment. – Driver implementation for peripheral control through its interface	Role-playing Parts of the base project: – Part I – Part II – Part III – Personalized assessment on the work done	Two individual partial tests, with two parts each, corresponding to the division of the syllabus, scored from 0 to 10. The work group students who, after the individualized assessment of the assignments, pass the tests, need not sit the partial tests to pass the course.
ADS	3	– Temporal characterization – Arithmetic circuits – Synchronization	– Role-playing – Debates Parts of the base project: – Part I – Part II – Part III	It will account for 25% of the final mark of the continuous assessment. 25% for theoretical tests, and 50% lab project assignment.

TABLE V. *QUANTITATIVE RESULTS FOR THE INVOLVED SUBJECTS*

Subject	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CST2 (TECM) Group 2	87	4/3	46	29	8	25	5	4	3
SC (TECS) Group 1	69	3	8 (partial 1) 4 (partial 2)	5(partial1) 3 (partial 2)	15(partial 1) 9 (partial 2)	3(partial 1) 2 (partial 2)	10 (partial 1) 4 (partial 2)	2 (partial 1) 1 (partial 2)	5 (partial 1) 5 (partial 2)
SC (TECS) Group 2	67	3	14 (partial 1) 5 (partial 2)	9(partial1) 5(partial 2)	12(partial 1) 3 (partial 2)	4(partial 1) 2 (partial 2)	4 (partial 1) 1 (partial 2)	5 (partial 1) 3 (partial 2)	8 (partial 1) 2 (partial 2)
SC (TECS) Group 3	85	3	10	9	13	6	8	3	5
CS (ECS) Group 1	58	3/4	7	7	18	7	14	0	4
CS (ECS) Group 2	41	3	15	14	10	13	9	1	1
PI	94	4	64	2	25	60	16	0	7
ADS	12	3	3	3	0	3	0	0	0

(1) Number of students enrolled
(2) Number of students per workgroup
(3) Number of students who did assignments
(4) Number of students who took a test and did their assignments
(5) Number of students who took a test and did NOT do their assignments
(6) Number of students who passed and did their assignments
(7) Number of students who passed and did NOT do their assignments
(8) Number of students who failed and did their assignments
(9) Number of students who failed and did NOT do their assignments

V. RESULTS

By analyzing the number of students who took a test and did their assignments (column 4 at TABLE V) and the number of students who passed and did their assignments (column 6 at TABLE V), we can get that, on average, 80% of students who use this methodology pass the subject in continuous assessment or in term-end examinations.

On the contrary, if we analyze the number of students who took a test and did NOT do their assignments (column 5 at TABLE V) and the number of students who passed and did NOT do their assignments (column 7 at TABLE V) we observe that, on average, among the students who took the test but did not use this methodology, 54% failed.

We see that there is a significant deviation in the number of students who use this methodology in the different subjects

and groups. We believe that this difference may be due to several reasons:

- In some subjects the methodology has not been implemented from the beginning of the semester, therefore there is no continuity in the implementation of these methods and their execution is late, when the student has already lost motivation in the subject.
- In some subjects a partial application of the methodology has been carried out (only Role-playing - Part III - is applied, but not the rest) and, curiously enough, the "passed" percentages obtained are lower (67%, 40 % and 67% for TECS groups 1, 2 and 3, respectively, and 86%, 100%, 93%, 93%, 100% for CST group 2, CS groups 1 and 2, the IP group and ADS group, respectively).

We must also take into account some peculiarities:

- In CS (II), each base group faced all three roles simultaneously: each group with respect to their peers had to assume the role of the teacher, reviser-editor and student.
- In CS (II), participation was planned for the third lesson of the term, which is evaluated in Test 2 of the three the subject has. At this stage of the term, dropping the course reached the usual high percentage in the last four academic years.
- In CS (II) group 1, the apparent "complete success" in terms of participants is due, at least in part, to the fact that the percentage of volunteers was low and the participants were the best students (those who excel in any system).
- In ADS the 3 participating students represented the total number of students in the course. The other 9 enrolled students never attended class or submitted any assignment.

VI. CONCLUSIONS

From an educational point of view, the implementation of this educational initiative has entailed:

- The study and experimentation with methodologies whose application is not usual in the courses taught.
- The carrying out of a methodological change aimed at learning and assessing the transversal skills that complement the assimilation of course content. The methodology allows to further assess subject-specific skills.
- Promoting the use of active learning methodologies.
- The analysis and promotion of different ways of group work.
- The design of practical teaching activities.
- The design and implementation of new assessment systems.

Having implemented this methodology, we can state that:

- It is undeniable that in carrying out this experience time and effort was spent to organize the activities, coordinate the work groups and review the students' ongoing assignments, which is added to the regular teaching activity. However, the following positive aspects can be noted:
  - Easy and quick detection of weaknesses in the (individual or collective) learning of subjects so that special attention can be paid to them in classroom lessons.
  - Students become more involved in the subject, know and treat their classmates with more familiarity, and classes are more interactive, which will have positive implications in the learning experience.
  - In general, by using these techniques, students' grades are higher than they usually are, provided they are applied throughout the course and in a continuous fashion. For example, for CST(2) group 2 the percentage of students who passed the course in the first-term exam for the academic year 2007/2008 was 33%, while that of the academic year 2008/2009 was 70%.
- The main difficulties encountered were:
  - The high number of students. The courses involved in the project have an average of 77 officially enrolled students per class. Although the dropout rate is high, even from the beginning of the course, an average of 55 students often remain in class. So, in some cases, as we have seen, it involves a large number of working groups per teacher. With such a number of students / groups, we find that:
    - Group management is complex, especially during the first three weeks of the course. It is understood that it is just a matter of experience in the application of these techniques.
    - The application of the puzzle technique in the classroom is difficult for two reasons: first, the teacher cannot cope with the monitoring of the progress of the expert meetings and, secondly, the activity is very noisy. The first problem could be solved through the collaboration of student interns to assist in managing the work of groups during the group sharing sessions, and the second disadvantage begins to disappear as students become accustomed to this way of working.
    - Narrowing which parts of the syllabus can be set aside for cooperative activities and which parts are not is a complex task. The content of these courses is dense and it is not trivial to discern what is accessory.
- Explaining the new method. The teacher must devote classroom time to explain how the new method works and what the procedure to be followed by students is. That time is subtracted from the teaching of the subject,

but we think it is not wasted time because the student's achieved understanding of the material is deeper.

- First-year students are more confused by the many changes, so we consider it more appropriate to apply these techniques in second term subjects.

Finally, note that some of the factors used for assessment (and rating) of each student in each base group were:

- Rule compliance: deadlines, submission of reports and maintaining base group meetings.
- The information provided by students: time spent, resources used, interaction with other group members, group self-assessment and co-assessment among members of the same base group (through the use of headings, for example).
- The teacher's grade on the assignments produced and students' tasks directly supervised by the teacher.

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REFERENCES

[1] ARONSON, E. (1978). The jigsaw classroom. Beverly Hills, CA: Sage publications.

[2] BEETS, S.D. (2003). Differences in student learning techniques: cooperative learning, quizzes, and homework. Journal of the Academy of Bussiness Education, 1-11.

[3] CUSEO, J.B. (1996). Cooperative Learning: A pedagogy for Addressing Contemporary Challenges & Critical Issues in Higher Education, Marymont College, New Forum Press.

[4] Espacio Europeo de Educación superior. Disponible en: http://www.eees.es/ [Consulta: 12 de mayo 2009]

[5] FOWLER, L. (2006). Active learning: an empirical study of the use of simulation games in the introductory financial accounting class. Academy of Educational Leadership Journal, 10(3), 93-103. [Consultado el 12 de mayo de 2009, desde ABI/INFORM Global database, (Document ID: 1291466841)].

[6] GIL, C. y GIL, M.D. (2009). Taller de formación – Metodologías Activas: Estrategias de Aprendizaje Cooperativo, Instituto de Ciencias de la Educación, Universidad de Sevilla, Sevilla.

[7] GÓMEZ, I.M. y otros (2007). Necesidades del profesorado de la Universidad de Sevilla respecto a las metodologías de enseñanza de cara a la adaptación al EEES, Proyecto de la Convocatoria de Ayuda a la Docencia para la Innovación (curso 2006/2007), Instituto de Ciencias de la Educación, Universidad de Sevilla.

[8] GÓMEZ, I.M. y otros (2006). Aplicación de técnicas de evaluación continua en grupos numerosos de alumnos, Proyecto de la Convocatoria de Ayuda a la Docencia para la Innovación (curso 2006/2007), Instituto de Ciencias de la Educación, Universidad de Sevilla.

[9] GÓMEZ, I.M. y otros (2005). Aplicaciones del sistema de créditos europeo a la actividad de las tutorías (USE N071), Proyecto Andaluz de Formación del Profesorado Universitario (Convocatoria 2004), Unidad para la Calidad de las Universidades Andaluzas (UCUA).

[10] GÓMEZ, I.M. y otros (2004). Mejora de la enseñanza basada en la autoevaluación docente (55-T-USE 14), Proyecto Andaluz de Formación del Profesorado Universitario (Convocatoria 2003), Unidad para la Calidad de las Universidades Andaluzas (UCUA).

[11] ONTORIA PEÑA y otros (2006). Aprendizaje centrado en el alumno: Metodología para una escuela abierta. Editorial Narcea.G. Eason, B. Noble, and I. N. Sneddon, "On certain integrals of Lipschitz-Hankel type involving products of Bessel functions," Phil. Trans. Roy. Soc. London, vol. A247, pp. 529–551, April 1955. (references)