# Cooperative Learning vs. Project Based Learning

a practical case

Jorge E. Pérez, Javier García, Isabel Muñoz
Departamento de Informática Aplicada
Universidad Politécnica de Madrid
Madrid, Spain
{jeperez, jgarcia, imunoz}@eui.upm.es

Almudena Sierra Alonso
Departamento de Ciencias de la Computación
Universidad Rey Juan Carlos
Madrid, Spain
almudena.sierra@urjc.es

Pilar López Puche
Departamento de Matemática Aplicada
Universidad Politécnica de Madrid
Madrid, Spain
plpuche@eui.upm.es

*Abstract*— **The Bologna Declaration and the implementation of the European Higher Education Area are promoting the use of active learning methodologies such as cooperative learning and project based learning. This study was motivated by the comparison of the results obtained after applying Cooperative Learning (CL) and Project Based Learning (PBL) to a subject of Computer Engineering. The fundamental hypothesis tested was whether the academic success achieved by the students of the first years was higher when CL was applied than in those cases to which PBL was applied.**

**A practical case, by means of which the effectiveness of CL and PBL are compared, is presented in this work. This study has been carried out at the Universidad Politécnica de Madrid, where these mechanisms have been applied to the Operating Systems I subject from the Technical Engineering in Computer Systems degree (OSIS) and to the same subject from the Technical Engineering in Computer Management degree (OSIM). Both subjects have the same syllabus, are taught in the same year and semester and share also formative objectives.**

**From this study we can conclude that students' academic performance (regarding the grades given) is greater with PBL than with CL. To be more specific, the difference is between 0.5 and 1 point for the individual tests. For the group tests, this difference is between 2.5 and 3 points. Therefore, this study refutes the fundamental hypothesis formulated at the beginning. Some of the possible interpretations of these results are referred to in this study.**

***Collaborative work; Education; Engineering Education***

## I. INTRODUCTION

"On 28 and 29 April 2009, the Ministers responsible for higher education in the 46 countries of the Bologna Process met in Leuven and Louvain-la-Neuve to establish the priorities for the European Higher Education Area until 2020. They highlighted in particular the importance of lifelong learning, widening access to higher education, and mobility" [1]. They emphasized as well on the significance of Student-centered learning and the teaching mission of higher education. "Student-centred learning requires empowering individual learners, new approaches to teaching and learning, effective support and guidance structures and a curriculum focused more clearly on the learner in all three cycles" [2]. New active learning methodologies such as Cooperative Learning (CL) and Project Based Learning (PBL) are found among the new approaches adopted in teaching and learning.

Cooperative learning is the instructional use of small groups so that students work together to maximize their own and each other's learning [3], [4]. In this work CL has been applied with the jigsaw technique [5]. The comparison, between the effectiveness of CL and the lecture/discussion method in higher education, has been examined in several studies [3], [6]-[8]. PBL has been established in the field of engineering as a significant experience which promotes cognitive activities and long-life learning [9]-[12].

The Educative Innovation Group DMAE-DIA [13] of the Universidad Politécnica de Madrid has been using active learning methodologies such as CL and PBL [14]-[18] for several years. This group is aimed at: 1) achieving a more active students´ participation in the learning/teaching process; 2) improving student's academic performance by promoting specific competences and 3) developing new learning and assessment methodologies.

A practical case, by means of which the effectiveness of CL and PBL are compared, is presented in this work. This study has been carried out at the Universidad Politécnica de Madrid, where these mechanisms have been applied to the subject Operating Systems I of the degree in Technical Engineering in Computer Systems (OSIS) and to the same subject of the degree in Technical Engineering in Computer Management (OSIM). The aim of the study is to compare the advantages and disadvantages of CL and PBL when applied to Engineering. Among the criteria to be compared we can find: 1) the academic performance of students; 2) the drop-out rate and the time in which it took place; 3) the opinion of students with regard to different aspects of the subjects: assessment methodologies, teaching methodologies adopted or the level of difficulty of the subjects studied.

As far as we are concerned, no studies of this nature which make a comparison between CL and PBL have been published. There are, however, some publications which differentiate between Project Based Learning and Problem Based Learning [19], [20], between Problem Based Learning and the traditional educational methodology [21], [22] as well as between CL and the traditional development of lectures [6], for instance. Hence the importance of this study, due to its originality.

The hypothesis of work is that the academic success achieved by students would be higher when CL is applied to the subject than in those cases in which PBL is applied. Two reasons support this idea: 1) The lack of maturity noticed in students during the first year to organize learning by themselves; 2) CL (as a "jigsaw") entails a more directed learning process than PBL. Therefore, a better academic performance is expected.

This paper is structured as follows: the number of participants who took part in the study, the teaching practice developed and the way in which data analysis was carried out are described in section 2. Section 3 presents the study results as well as a discussion about them. Section 4 is used to make a brief description of an experience in which both methodologies (CL and PBL) where combined and applied to two subjects of Computer Engineering. Finally, the main conclusions of this work are presented in section 5.

## II. METHOD

### *A. Participants*

This study has been carried out at the Universidad Politécnica de Madrid, where CL and PBL have been applied to Operating Systems I subject of the degree in Technical Engineering in Computer Systems (OSIS) and to the same subject of the degree in Technical Engineering in Computer Management (OSIM). Both subjects have the same syllabus, are taught in the same course and semester and share also formative objectives. The latter syllabus, OSIM, has been taught applying PBL to a group of 60 students, who were put together into an only group. The former, OSIS, has been taught applying CL to 107 students, who were divided into two groups. The three professors who have taught these subjects are highly experienced both in teaching the subjects and in using CL and PBL.

### *B. Procedure*

Both subjects, OSIS and OSIM, are broken down into five topics: Introduction, Process and Threads, Memory Management, Input/Output and File Systems. Students had only one book of reference [23] to meet all these topics. Both subjects, OSIS and OSIM, were taught for 15 weeks, with two-hour sessions per week.

In the subject SOIM the tasks which constitute the project will be carried out by groups of 4 or 5 students. This project is aimed at making a comparison between the operating systems Windows XP and Linux along the course, regarding the aspects included in the syllabus of the subject. At the end of the term, students should be able to explain a series of essential differences and similarities between both operating systems, from the point of view of their interface, implementation and performance. The project will be divided into 4 tasks. Students will tackle a different topic in each of the works, which will be related to the contents of the syllabus. The professor will suggest a series of topics; however, any group can work on another topic suggested by them, which has to be previously agreed with the professor. The development of each topic consists of three phases. First, students carry out a search and study of information. Then, they have to design an experiment approaching the comparison between Linux and Windows XP, with regard to the topic studied. Finally, they present a report with all the work carried out, including the results obtained in the experiment, and also make an oral presentation. At the end of the term, a debate is established focusing on all the projects developed by students in order to answer a series of open questions: Are Linux and Windows XP actually so different? Is there any significant difference regarding their performance? Does any of the operating systems offer more advantages from the point of view of programming?

On the other hand, CL was applied to the fifteen OSIS sessions. At the beginning of the course, permanent groups of four students (base groups) were formed. Because of CL, each member of a group had to be an expert on some basic concepts of the topic during each session. For this reason, the homework students were given depended on the type of expert. There were four kinds of homework, one addressed to each expert. For each session, this homework was structured into three parts: the first described the learning objectives and skills to be acquired with the homework; the second indicated the information to be studied, and the third part consisted in solving basic problems, developing a simple program or answering some questions. Both the second and the third part were set estimated periods of time to be carried out. Homework had to be handed to the professor before the session in question started and the real amount of time it took them to do it must be indicated. Along each session, CL method was put into practice and all base groups tried to solve a problem which required the knowledge of the four experts (jigsaw). At the end of the session there was a global discussion about the difficulties encountered and the different ways to solve the problems.

### *C. Measurements and instruments*

Three different types of measurements were used: the ones corresponding to academic performance, the ones relative to the drop-out rate and those regarding the opinion survey responded by students.

- Academic performance. It is considered as the set of grades achieved along the semester. Both grades, the ones achieved in specific tests of each methodology (group grades) and those grades achieved in multiple-choice exams (individual grades) are taken into account.

In the subject OSIM the final grade consists of two parts: an individual mark (50%) and a group mark (the mark obtained in the project carried out in group, 50%). Individual marks are made up of 4 tests (20%), some questionnaires with short questions (10%) and problem solving activity (20%). Each part of the project is assessed in two ways: 1) Co-assessment (50%) - each group has to assess the work carried out by the other groups as well as to classify them regarding their quality. Students are awarded a grade according to the mark they have been given and to the position reached in the ranking; 2) Professor's assessment (50%) - the professor makes a correction of each students' assessment and awards them the remaining 50% of the grade. In order to carry out these two assessments, rubrics with the criteria to be considered are provided for each of them. These rubrics are at students' disposal so that they are aware of the criteria demanded before carrying out every phase of the project.

In the subject OSIS a continuous assessment method was followed so as to evaluate achieved specific competences of the subject. During the course, four different kinds of activities were used, all of which were assessed: lab exercises, tests, CL and individual homework. The final grade consists of two parts: an individual mark (40%) and a group mark (60%). Individual marks are made up of 5 tests (20%), and 3 individual assessments (20%). Group marks are made up of 6 assessments (40%) and 5 lab exercises (20%). The individual assessments consisted in carrying out a short question or exercise which had been chosen from the homework of the session. Some of the tests and individual assessments were assessed by other classmates (peer-evaluation). In order to pass the course, students must achieve a minimum grade of 50% and at least a third must be achieved in each evaluated part.

- Drop-out. The drop-out rate and the time in which it took place are considered, as well as their relationship to the different phases of implementation of both methodologies.

  At the beginning of the OSIM course, 39 out of 60 students started the project. These students were divided into 9 groups. These groups handed in the first of the four topics of which the project was constituted, although two groups (a total of 9 students) dropped out before submitting the second task and stopped attending classes. One of them had been awarded a low grade in the assignment they had handed in, while the other group achieved a considerably high grade (7.6 out of 10).

  In the subject OSIS, the total number of students who dropped out the course was 27. During the first topic, which took four sessions, 18 students dropped out because they realized they were not able to dedicate 110 hours making a continuous effort for 15 weeks. The remaining drop-outs took place at the end of each topic; the rate was significantly lower at that moment, though, since only three students drop the course out after topics 2 and 3, two students after topic 4 and just one student after topic 5.

  Therefore, the fact that most of the drop-outs, both with PBL and CL, took place during the first month of the course can be inferred from the information given above. The hypothesis considered is that students notice during the first month the workload required by the subject and consider whether they would be able or not to devote the time needed. However, more data are necessary in order to confirm the hypothesis.

- Opinion survey. At the end of the term, students respond to an opinion survey with questions about specific aspects studied along the course. In this section, the most important results obtained from the students' opinion are shown. Questions directly related to the contents of the course were excluded. In the first block, we asked four questions regarding the effectiveness of each methodology. Students' opinion is indicated below in a scale which ranges from 1 to 5:

  1.- I consider the level of difficulty of the matters raised in the tests according to the themes studied in class to be:

| | OSIM | OSIS |
|---|---|---|
| 5.- Very difficult | 12 % | 22 % |
| 4.- Quite difficult | 64 % | 53 % |
| 3.- Appropriate | 16 % | 20 % |
| 2.- Quite easy | 8 % | 3 % |
| 1.- Very easy | 0 % | 2 % |

  2.- On the whole, I think that I have learnt a lot about operating systems and this knowledge will be permanent to a large extent:

| | OSIM | OSIS |
|---|---|---|
| 5.- Totally agree | 16 % | 6 % |
| 4.- Quite agree | 32 % | 36.5% |
| 3.- Agree | 40 % | 39 % |
| 2.- Quite disagree | 8 % | 12.5% |
| 1.- Totally disagree | 4 % | 6 % |

  3.- In general, I believe that PBL/CL methodology has helped me understand better and acquire deep knowledge of the concepts:

| | OSIM | OSIS |
|---|---|---|
| 5.- Totally agree | 4 % | 6 % |
| 4.- Quite agree | 40 % | 39 % |
| 3.- Agree | 44 % | 35 % |
| 2.- Quite disagree | 12 % | 15 % |
| 1.- Totally disagree | 0 % | 5 % |

  4.- Regarding the level of difficulty when it comes to understand the texts to be studied without any previous explanation, I find it:

| | OSIM | OSIS |
|---|---|---|
| 5.- Excessively high | 4 % | 16 % |
| 4.- High | 28 % | 51 % |
| 3.- Appropriate | 60 % | 28 % |
| 2.- Low | 0 % | 5 % |
| 1.- Really low | 8 % | 0 % |

Two questions related to the assessment strategies followed were made in order to know students' opinion about their effectiveness.

1.- The results obtained are a reflection of the personal effort I have made:

| | OSIM | OSIS |
|---|---|---|
| 5.- Totally agree | 4 % | 4 % |
| 4.- Quite agree | 16 % | 26 % |
| 3.- Agree | 24 % | 33 % |
| 2.- Quite disagree | 48 % | 30 % |
| 1.- Totally disagree | 8 % | 7 % |

2.- On the whole, I think that the assessment method used is better than the conventional, which was only based on the final test.

| | OSIM | OSIS |
|---|---|---|
| 5.- Totally agree | 48 % | 39 % |
| 4.- Quite agree | 24 % | 33 % |
| 3.- Agree | 16 % | 24 % |
| 2.- Quite disagree | 12 % | 1 % |
| 1.- Totally disagree | 0 % | 3 % |

### D. *Data Analysis*

For the Statistical Analysis we used version 5.1 of the statistical program STATGRAPHICS. The statistical techniques for the analysis were: for the distribution fitting to determine if data can be adequately modelled by a normal distribution we used Kolmogorov_Smirnov test and superimposed the PDF of the fitted normal distribution. We run F-Snedecor test to decide whether the equality of variances must rejected. We run a t-test with an m+n-2 freedom degree to decide if the equality of the means could be considered in those cases in which the equality of variances could not be rejected and the Welch approximation was ran whenever the equality of variances had been rejected. To decide whether the equality of percentages must be rejected or not, we run a Hypothesis Test for Difference Between Proportions.

## III. RESULTS AND DISCUSSION

We carried out a comparison of the grades in both methodologies.

### A. *Analysis of the grades achieved in the test with PBL and CL methodologies*

The first step was to conduct an exploratory examination of the data. This was carried out both analytically and graphically. We used the statistical software Statgraphics. Table I shows some statistics. GTEST_G variable corresponds to the subject OSIM, while STEST_G variable refers to the subject OSIS. Fig. 1 shows the histogram and density estimated [24] for the test grades achieved in OSIM, to which PBL methodology had been applied. Fig. 2 shows the histogram and density estimated for the test grades achieved in OSIS, to which CL methodology had been applied.

The results of the test ran in order to determine whether GTEST_G and STEST_G can be adequately modelled by a normal distribution are shown. The Kolmogorov-Smirnov test has been performed.

| |
|---|
| Tests for Normality for GTEST_G<br><br>Kolmogorov-Smirnov test<br>Estimated overall statistics DN=0.0770702<br>Approximate P-Value = 0.99281 |

| |
|---|
| Tests for Normality for STEST_G<br><br>Kolmogorov-Smirnov test<br>Estimated overall statistics DN=0.0869847<br>Approximate P-Value = 0.357309 |

Since in the test which has been carried out the computed P-value is not less than 0.05, the null hypothesis that STEST_G and GTEST_G come from a normal distribution with a 0.05 level was not rejected.

TABLE I. SUMMARY STATISTICS

| | GTEST_G | STEST_G |
|---|---|---|
| Count | 31 | 114 |
| Average | 4.89032 | 3.79737 |
| Median | 4.6 | 3.9 |
| Mode | 4.1 | 4.6 |
| Variance | 3.58424 | 2.73282 |
| Standard deviation | 1.89321 | 1.65313 |
| Minimum | 0.8 | 0.0 |
| Maximum | 8.7 | 8.5 |
| Range | 7.9 | 8.5 |
| Lower quartile | 3.7 | 2.9 |
| Upper quartile | 6.1 | 4.7 |
| Skewness | -0.0181856 | -0.208458 |

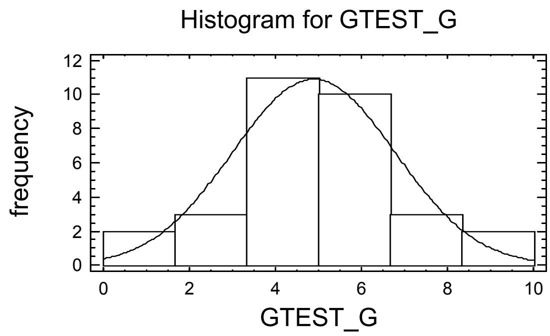


Figure 1.

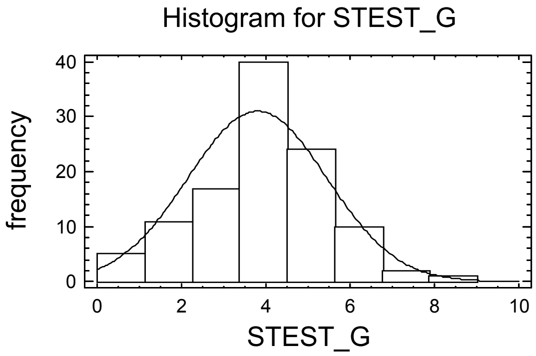


Figure 2.

After that, a comparison of GTEST_G and STEST_G, the two teaching methods for OSIM and OSIS, was carried out. Fig. 3 shows the box-plot of the data.

They turn out to be different. The length and the interquartile ranges of the group GTEST_G are not similar to those of the group STEST_G. The data of the groups GTEST_G and STEST_G were modelled as realizations of random samples X1, X2,…, Xm and Y1, Y2,...,Yn with m=31 and n=114 from two distributions: one with the expected value μ1 and the other with the expected value μ2; the hypothesis of the test was: H0: μ1=μ2 against H1: μ1≠μ2.

First, we had to decide whether there is a statistically significant difference between the standard deviations of the two samples. An F-test [25] was ran so as to compare standard deviations. In this case: H0: σ 1= σ 2 against H1: σ 1≠ σ 2. Since the computed P-value is not less than 0.05, the equality of variances cannot be rejected. These results are shown in Table II.

Then, a t-test was carried out to compare the means of the two samples. A t-test was used: $H_0:\mu_1=\mu_2$ against $H_1:\mu_1\neq\mu_2$. Since the computed P-value is less than 0.05, the null hypothesis can be rejected in favour of the alternative. These results are shown in Table III.

As the confidence interval is as well shown for the difference of means (confidence 0.95), the following tests can be considered according to this. A t-test was run once again. In this case: $H_0:\mu_1-\mu_2 \leqslant 0.5$ against $H_1:\mu_1-\mu_2>0.5$. Since the computed P-value is lower than 0.05, the null hypothesis was rejected. Thus, we have to admit that there is a considerable difference with a 0.05 significance level between the means of the grades in GTEST_G and STEST_G, which is 0.5 points greater than. These results are shown in Table IV.

Finally, a t-test was performed again. In this case, the test had been carried out to determine whether the difference between the two means is equal or less than 1, versus the alternative hypothesis which states that the difference is greater than 1. $H_0:\mu_1-\mu_2\leqslant 1$ against $H_1:\mu_1-\mu_2>1$. Since the computed P-value is not less than 0.05, the null hypothesis cannot be rejected. Then we have to admit with a 0.05 level that there is a significant difference between the means of the grades of the test performed in the two groups, and the idea that the difference between the grades in GTEST_G and STEST_G is lower than 1 point cannot be rejected. These results are shown in Table V.

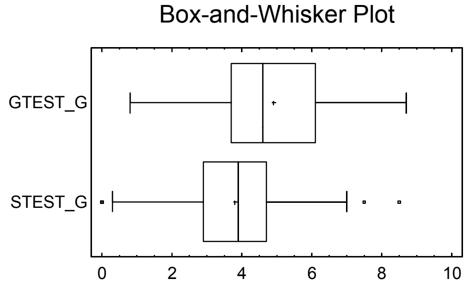


Figure 3.

TABLE II. COMPARISON OF STANDARD DEVIATIONS

| | GTEST_G | STEST_G |
|---|---|---|
| Standard deviation | 1.89321 | 1.65313 |
| Variance | 3.58424 | 2.73282 |
| Df | 30 | 113 |

Ratio of Variances = 1.31155

F-test to Compare Standard Deviations

Null hypothesis: sigma1 = sigma2
Alt. hypothesis: sigma1 NE sigma2
F = 1.31155 P-value = 0.312464

NOTE: these results assume that the distributions of the two samples can be adequately modelled by a normal distributions.

TABLE III. COMPARISON OF MEANS

95,0% confidence interval for the difference between the means assuming equal variances: 1.09295 +/- 0.683195 [0.409759,1.77615]

t test to compare means
Null hypothesis: mean1 = mean2
Alt. hypothesis: mean1 NE mean2
assuming equal variances: t = 3.16226
P-value = 0.00191215

TABLE IV. COMPARISON OF MEANS

t test to compare means
Null hypothesis: mean1 - mean2 = 0.5
Alt. hypothesis: greater than
assuming equal variances: t = 1.7156
P-value = 0.0442005

TABLE V. COMPARISON OF MEANS

| t test to compare means |
|---|
| Null hypothesis: mean1 - mean2 = 1.0 |
| Alt. hypothesis: greater than |
| assuming equal variances: t = 0.268945 |
| P-value = 0.39418 |

These results consider the variances of the two samples to be equal. In this case, that assumption appears to be reasonable based on the results of an F-test which was carried out to compare the standard deviations (Table II).

To summarize, we have to admit that the grades achieved in the test with GTEST_G are greater than the grades achieved in the test with STEST_ G, between 0.5 and 1 point. Significance level: 0.05.

### B. *Analysis of the grades achieved in students group works with PBL and CL methodologies*

A comparison on the grades in both methodologies was carried out. Therefore, the same steps than in the case of the comparison of the grades achieved in the test were followed. The first step was to carry out an exploratory examination of the data. Table VI shows some statistics.

Fig. 4 shows the histogram and density estimate of the grades achieved in OSIM, and Fig. 5 shows the histogram and density estimate of the grades achieved in OSIS.

The results of the Kolmogorov-Smirnov test performed in order to determine whether GGroup_G and SGroup_G can be adequately modelled by a normal distribution are shown.

Since in every test carried out the computed P-value is not lower than 0.05, the null hypothesis that GGroup_G and SGroup_G come from a normal distribution with 0.05 level was not rejected.

Next, a comparison between GGroup_G and SGroup_G, the two teaching methods for OSIM and OSIS, was carried out. Fig. 6 shows the box-plot of the data.

| Tests for Normality for GGroup_G |
|---|
| Kolmogorov-Smirnov test |
| Estimated overall statistic DN = 0.211216 |
| Approximate P-Value = 0.125848 |

| Tests for Normality for SGroup_G |
|---|
| Kolmogorov-Smirnov test |
| Estimated overall statistic DN = 0.123826 |
| Aproximate P-Value = 0.0606438 |

They turn out to be different. The length and the interquartile ranges of the group GGroup_G are not similar to those of the group SGroup_G. The data of the groups GGroup_G and SGroup_G were modelled as realizations of random samples $X_1, X_2,...,X_m$ and $Y_1, Y_2, ...,Y_n$ with m=31 and n= 114 from two distributions; one with the expected value $\mu_1$ and the other with the expected value $\mu_2$; the hypothesis of the test was: $H_0$: $\mu_1=\mu_2$ against $H_1$:$\mu_1\neq\mu_2$.

TABLE VI. SUMMARY STATISTICS

| | GGroup_G | SGroup_G |
|---|---|---|
| Count | 31 | 114 |
| Average | 7.62258 | 4.34737 |
| Median | 7.4 | 4.7 |
| Mode | | |
| Variance | 0.445806 | 3.1142 |
| Standard deviation | 0.667687 | 1.76471 |
| Minimum | 5.5 | 0.0 |
| Maximum | 8.6 | 7.7 |
| Range | 3.1 | 7.7 |
| Lower quartile | 7.3 | 3.7 |
| Upper quartile | 8.1 | 5.4 |
| Interquartile range | 0.8 | 1.7 |
| Skewness | -0.81226 | -0.558472 |
| Coeff. Of variation | 8.75934% | 40.5926% |

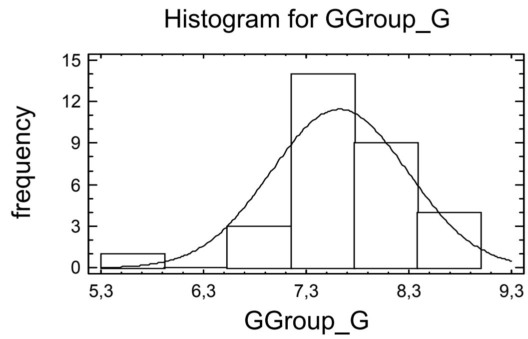


Figure 4.

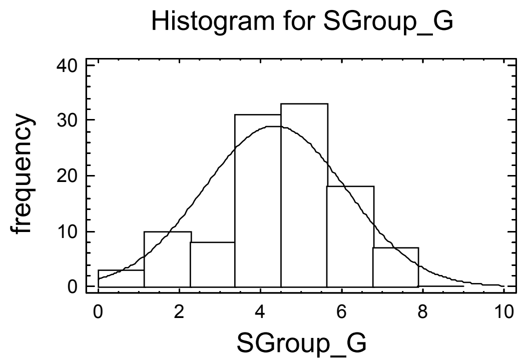


Figure 5.

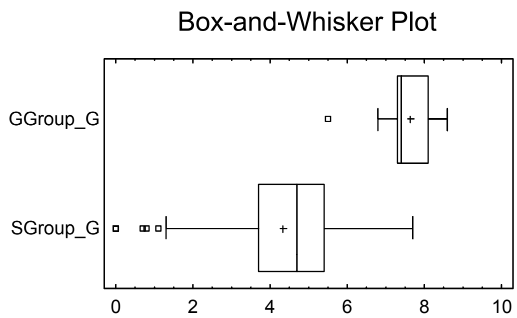


Figure 6.

First, we had to decide whether there is a statistically significant difference between the standard deviations of the two samples. An F-test was run so as to compare standard deviations. In this case: $H0: \sigma 1 = \sigma 2$ against $H1: \sigma 1 \neq \sigma 2$. Since the computed P-value is less than 0.05, the equal of variances can be rejected. These results are shown in Table VII.

Then, a t-test was carried out to compare the means of the two samples. A t-test was used: $H0: \mu 1 = \mu 2$ against $H1: \mu 1 \neq \mu 2$. Since the computed P-value is less than 0.05, the null hypothesis in favour of the alternative can be rejected. These results are shown in Table VIII.

As the confidence interval is as well shown for the difference of means (confidence 0.95), the following tests can be considered according to this (Table VIII).

A t-test was run again. In this case: $H0: \mu 1 - \mu 2 \leqslant 2.5$ against $H1: \mu 1 - \mu 2 > 2.5$. Since the computed P-value is less than 0.05, the null hypothesis was rejected. Then we have to admit that there is a considerable difference with a 0.05 significance level between the means of the grades in GGroup_G and SGroup_G, which is greater than 2.5 points. These results are shown in Table IX.

Finally, another t-test was carried out. In this case, the test had been constructed in order to determine whether the difference between the two means is equal or less than 3, versus the alternative hypothesis which states that the difference is greater than 3. $H0: \mu 1 - \mu 2 \leqslant 3$ against $H1: \mu 1 - \mu 2 > 3$.

Since the computed P-value is not less than 0.05, the null hypothesis cannot be rejected. Then we have to admit with a 0.05 level that there is a significant difference between the means of the grades achieved by two groups in the test, and the idea that the difference between the grades achieved in GGroup_G and in SGroup_G is less than 3 points cannot be rejected. These results are shown in Table X.

These results consider the variances of the two samples to be not equal. In this case, that assumption appears to be reasonable based on the results of an F-test which was carried out to compare the standard deviations (Table VII). Different tests were performed for the Two-Sample Comparison, although one P-value was near 0.5 considering that the absence of normality has normally no influence on the F-test run by ANOVA and in the comparison of means [25].

To conclude, we have to admit that the grades achieved in GGroup_G are greater than the grades achieved in SGroup_G, between 2.5 and 3 points. Significance level: 0.05.

### C. *Analysis of the opinion survey*

We had to decide whether there is a statistically significant difference between the percentages of the opinion survey answers given by the students of both methodologies. In this case we used an statistic T whose distribution is approximately N (0,1). We noted t the value of this statistic assuming equal proportions.

Relating to question 1 ("I consider the level of difficulty of the matters raised in the tests according to the themes studied in class to be: very difficult, quite difficult, appropriate, quite easy or very easy") we obtained the comparison of proportion shown in Table XI.

TABLE VII. COMPARISON OF STANDARD DEVIATIONS

| | GGroup_G | SGroup_G |
|---|---|---|
| Standard deviation | 0.667687 | 1.76471 |
| Variance | 0.445806 | 3.1142 |
| Df | 30 | 113 |

F-test to Compare Standard Deviations

Null hypothesis: sigma1 = sigma2
Alt. hypothesis: sigma1 NE sigma2
F = 0.143153 P-value = 6.71803E-8

TABLE VIII.

Two-Sample Comparison - GGroup_G & SGroup_G

Comparison of Means
-------------------
95,0% confidence interval for the difference between the means not assuming equal variances: 3.27521 +/- 0.404024 [2.63468,3.91575]

t test to compare means

Null hypothesis: mean1 = mean2
Alt. hypothesis: mean1 NE mean2
not assuming equal variances: t = 16.0391
P-value = 0.0

TABLE IX.

Two-Sample Comparison - GGroup_G & SGroup_G

Comparison of Means
-------------------

t test to compare means

Null hypothesis: mean1 - mean2 = 2.5
Alt. hypothesis: greater than
not assuming equal variances: t = 3.7963
P-value = 0.000112408

TABLE X.

Two-Sample Comparison - GGroup_G & SGroup_G

Comparison of Means
-------------------

t test to compare means

Null hypothesis: mean1 - mean2 = 3.0
Alt. hypothesis: greater than

not assuming equal variances: t = 1.34775
P-value = 0.0900526

In Table XI, P1* y P2* are the proportion of students who answered appropriate, quite difficult or very difficult in OSIM and OSIS respectively and p* is the pooled proportion. Since the value obtained (assuming H0) is t = -0.7371, greater than -1.96 and less than 1.96, values from the Normal distribution for α=0.05, the null hypothesis cannot be rejected for this significance level. Similar results have been obtained in questions 2 (t= 1.11836) and 3 (t = 0.2835). Therefore we have to admit that the percentages of the answers given follow very similar criteria and no significant differences can be established regarding the assessment made by students of both subjects. It has to be highlighted that students have a good opinion about the methodologies applied to both subjects and believe to have acquired a deep knowledge in the two of them.

Relating to question 4 ("Regarding the level of difficulty when it comes to understand the texts to be studied without any previous explanation, I find it: Excessively high, high, appropriate, low or really low") we obtained the comparison of proportion shown in Table XII.

In Table XII, P1* y P2* are the proportion of students who answered appropriate, low or really low in OSIM and OSIS respectively. Since the value obtained from the statistic (assuming H0) is t=3.2157 greater than 1.65, value from the normal distribution for α=0.05, the null hypothesis must be rejected for this significance level. Therefore we have to admit that the percentage of students who answered appropriate, low or really low is greater in OSIM than the percentage of students who answered appropriate, low or really low in OSIS. In this respect, it is worth pointing out that some master classes have been programmed in order to help with the development of the subject OSIM; some basic theoretical issues were taught during these classes before the beginning of the student work. However, students had to deal with the study of OSIS before the subject had started.

TABLE XI.

Comparison of Proportions
OSIM OSIS
-----------------------------------------------------------
$P_1$* = 0.92 $P_2$* = 0.9557
p*= 0.9493
Null hypothesis: $P_1 = P_2$
Alt. hypothesis: $P_1$ NE $P_2$
Assuming $H_0$ the value of T: t= -0.7371

TABLE XII.

Comparison of Proportions
OSIM OSIS
-----------------------------------------------------------
$P_1$* =0.68 $P_2$* = 0.3302
p*=0.3969
Null hypothesis: $P_1 = P_2$
Alt. hypothesis: $P_1$ greater than $P_2$
Assuming $H_0$ the value of T: t= 3.2157

Concerning the two questions related to the assessment strategies, the comparison of proportions produced t = -1.7244 (question 1) and t = -1.6452 (question 2). Since these values of the statistic are greater than -1.96 and less than 1.96 , values from the Normal distribution for α=0.05, the null hypothesis (P1 = P2) cannot be rejected for this significance level. Consequently, we have to admit that students of both subjects seem to fully agree with the fact that the assessment method used is better than the conventional one, in which 80% of the grade was achieved in a final exam (the remaining 20% was achieved after carrying out some practical activities).

## IV. AND, WHY NOT TO COMBINE CL AND PBL?

In spite of the fact that CL and PBL have proved to be useful regarding the meaningful learning acquired by our students, it is necessary to combine them at some point in order to reach an effective learning process. While an experiment was performed in order to make a comparison between CL and PBL in the Operating System subject, another experiment which combined both methodologies was conducted meanwhile, during the same course. Such experiment was tried in two subjects. The first experience was carried out in the subject Real Time Systems of the degree in Technical Engineering in Computer Systems at the Universidad Politécnica de Madrid; the second, in the subject Software Engineering II of the degree in Technical Engineering in Computer Systems at the Universidad Rey Juan Carlos. These subjects were taught adopting a PBL methodology in both cases. The experience acquired in the last years has proved to increase students' motivation for studying the subject when PBL is applied. On the other hand, with the implementation of PBL students have slightly relaxed when it comes to deal with the theoretical study of some aspects which are essential for the development of the project, though. In these cases, the role of the professor as the leader and supervisor of acquiring learning (as it is suggested by the PBL methodology) is not enough. In turn, it seems to be more effective if individual learning sessions are turned into active learning by means of the implementation of CL, for instance [26].

In the subject Real Time Systems the development of the project is carried out by teams of three students. We scheduled two CL sessions in which all the members of a team worked together in order to solve a problem related to their project. Each session lasted for 110 minutes. One session was designed to work on the last two chapters of the course which were not covered by the development of the project (Fault Tolerance and High Integrity Systems). At the end of the session, a small problem was proposed to every team. The second session was designed with a different purpose: helping students when it comes specifically to develop a critical phase of the project. In this phase, students have to do a creative design work. It is very important to know clearly the theoretical concepts on which this task is based in order to be able to use them, so students should avoid relaxing in the theoretical study. Furthermore, it is advisable to have the professor supervise the design while students are carrying it out, as well as hold a debate with them to discuss the proposed solution. The result of this task has a great influence on the complexity which they will find in the development of further phases of the project. That is why achieving a certain level of quality in their design is so important. CL was applied to both sessions as a jigsaw [5]. Besides, by improving the team-working skill, these self-contained sessions turned out to be really helpful in order to complete the topics included in the syllabus and to overcome the critical phases of the project. Students showed enough knowledge in both cases. Moreover, this educational methodology was favourably welcomed by students. A 60% of them strongly agreed with the following statement: "Cooperative Learning is a helpful methodology to learn the contents of the subject" in an opinion survey which was carried out at the end of the course. A 27% of students simply agreed with this assertion and the remaining 13% disagreed.

In the subject Software Engineering II the project is carried out by teams of four students along 30 sessions of 2 hours each. As it is said above, applying CL helps us to avoid students relax when it comes to study the concepts which are not covered by the project. However, CL can as well be a way to guide and supervise students in the autonomous learning progress required by PBL. In this subject, for example, students must learn JAVA (they can program, but they do not know the language). In order to guide students, the professor schedules 8 CL sessions which last 110 minutes each. Different aspects of the language are studied in every session. At the end of the session, the team has to develop a program. This way the professor is able to guide the study of the elements of the language and to supervise students' learning regarding the quality of their program. Another important topic are testing methods. Although there are several testing methods, students will only use two or three of them in order to test their project. A CL session of 110 minutes is scheduled in order to force students to study and use each method at least once. This session allows the professor to guide and supervise the work of students. The professor guides them when it comes to selecting some literature which they must analyse and study. After the session every team has to prepare a collection of test cases using the different testing methods. Furthermore, an individual test is also carried out. Thus, the professor is able to supervise the individual learning process. In this subject the sessions are structured as a jigsaw, just like in the RTS course. In this case the educational methodology was favourably welcomed by students too.

## V. CONCLUSION

As it can be inferred from the results above, the work hypothesis cannot be proved. The lack of maturity of the students from the third term was one of the reasons that made us think of the idea that CL would give as a result a better academic performance. However, we have observed that students' performance is not affected by their lack of maturity when PBL methodology is supported by individual tuition addressed to each group of work. On the other hand, as it has been already proved in further studies [16], one of the advantages of PBL methodology is the increase in students' motivation, a fact that could be stated by OSIM professors. We are of the opinion that this aspect may have had a great influence on the academic results achieved. From our point of view, there are two possible ways of verifying this conclusion. First, another study should be carried out in order to calculate the different level of motivation among students from both methodologies and to establish a relationship to their academic performance. Second, we think that the study carried out in this work should be applied to other subjects and to different contexts so as to corroborate the results obtained.

## ACKNOWLEDGMENT

This research has been supported by the Universidad Politécnica de Madrid under project IE09611042.

## REFERENCES

[1] Bologna Process (2009, Apr). *Bologna+10 Ministerial conference* [Online]. Available: http://www.ond.vlaanderen.be/hogeronderwijs/bologna/

[2] Leuven/Louvain-la-Neuve Communiqué (2009, Apr. 28-29 ). *The Bologna process 2020 - The European Higher Education Area in the new decade* [Online]. Available: http://www.ond.vlaanderen.be/hogeronderwijs/bologna/conference/documents/Leuven_Louvain-la-Neuve_Communiqué_April_2009.pdf)

[3] Johnson, D. W. et al., *Active learning: Cooperation in the college classroom*. Edina, MN: Interaction Book Co., 1991.

[4] The Cooperative Learning Center at the University of Minnesota. http://www.co-operation.org.

[5] Jigsaw classroom. http://www.jigsaw.org/overview.htm

[6] Johnson, D.W. et al., *Cooperative Learning Methods: a Meta-Analysis*. Minneapolis, MN: University of Minnesota Press, 2000.

[7] Richard M. Felder & Rebecca Brent, "Effective strategies for cooperative learning", *J. of Cooperation & Collaboration in College Teaching*, vol.10, no. 2, pp. 69-75, 2001.

[8] Terenzini, P.T. et al., "Collaborative learning vs. lecture/discussion: student's reported learning gains", *J. of Eng. Educ.*, vol. 90, no. 1, pp. 123-130, 2001.

[9] R. Chaoming Hsu and Wen-Chung Liu, "Project based learning as a pedagogical tool for embedded system education", in *Int. Conf. Inform. Technology: Research and Educ.*, Hsinchu, Taiwan, 2005, pp. 362- 366.

[10] J. Froyd et al., "A project-based approach to first-year engineering curriculum development", in *35th ASEE/IEEE Frontiers in Educ. Conf.*, Indianapolis, IN, 2005, pp. T3H-T3H.

[11] Powers, S.E. de Waters, J., "Creating project-based learning experiences for univesity- K-12 partnerships", in *34th ASEE/IEEE Frontiers in Educ. Conf.*, Savannah, GA, 2004, pp. F3D- 18-23 Vol.2.

[12] Thomas, J.W., *Project based learning handbook*. Buck Institute for Education, 1999.

[13] DMAE-DIA Education Innovation Group http://c3po.eui.upm.es/dmae/dmaeing.html

[14] García Martín J. et al., "The application of educational methodologies to overcome critical issues in a project based learning", *in Int. Technology, Educ. and Develop. Conf.*, Valencia, Spain, 2007.

[15] Pérez Martínez, J.E. et al., "Cooperative Learning in Operating Systems Laboratory", *in 13th Annu. Conf. on Innovation and Technology in Comput. Sci. Educ.*, Madrid, Spain, 2008.

[16] Javier Garcia and Jorge E. Pérez, "A PBL Application Experience Supported by Different Educational Methodologies", in *Research on PBL Practice in Engineering Education*, Xiangyun Du, Erik de Graaff and Anette Kolmos, Eds. Rotterdam, The Netherlands: Sense Publisher, 2009, pp. 139-153.

[17] Javier Garcia and Almudena Sierra, "Approach to a Method to Organize PBL Courses" presented at the 2nd Int. Research Symp. on Problem Based Learning, Melbourne, Australia, 2009.

[18] Javier Garcia, "Co-assessment to Foster the Motivation for Quality and Continuous Improving in PBL", presented at the 2nd Int. Research Symp. on Problem Based Learning, Melbourne, Australia, 2009.

[19] Roisin Donnelly and Marian Fitzmaurice, "Collaborative project-based learning and problem-based learning in higher education: a

consideration of tutor and student role in learner-focused strategies", in *Emerging Issues in the Practice of University Learning and Teaching*, G., Moore, S., McMullin, B., Eds. Dublin:AISHE, 2005.

[20] Jon-Chao Hong et al., "The Comparison of Problem-based Learning (PmBL) Model and Project-based Learning (PtBL) Model" in *Int. Conf. on Eng. Edu.*, Coimbar, Portugal, 2007.

[21] Sandra K. Rich et al., "Problem-Based Learning versus a traditional educational methodology: A comparison of preclinical and clinical periodontics performance", *J. of Dental Edu.*, vol. 69, no. 6, pp. 649-662, Jun, 2005.

[22] Johannes Strobel and Angela van Barneveld, "When is PBL more effective? A meta-synthesis of meta-analyses comparing PBL to conventional classrooms", The interdisciplinary Journal of Problem-baed learning, vol. 3, no. 1, pp. 44-58, Spring 2009.

[23] Tanenbaum, A. S., *Modern Operating Systems*, 2ª ed., Upper Saddle River, NJ: Prentice Hall, 2001.

[24] F.M. Dekking et al., *A modern introduction to probability and statistics*, London, England: Springer-Verlag, 2005.

[25] Montgomery, D.C., *Design and analysis of experiment*, 5th ed, NY:John Wiley & Sons, 2001

[26] García Martín, J, "Cooperative Learning to Support the Lacks of PBL", *in 14th Annu. Conf. on Innovation and Technology in Computer Science Education*, Paris, France, 2009.