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Active Learning and Generic Competences in an Operating Systems Course*

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The Bologna Declaration and the implementation of the European Higher Education Area are promoting the use of active learning methodologies. The aim of this study is to evaluate the effects obtained after applying active learning methodologies to the achievement of generic competences as well as to the academic performance. This study has been carried out at the Universidad Politécnica de Madrid, where these methodologies have been applied to the Operating Systems I subject of the degree in Technical Engineering in Computer Systems. The fundamental hypothesis tested was whether the implementation of active learning methodologies (cooperative learning and problem based learning) favours the achievement of certain generic competences ('teamwork' and 'planning and time management') and also whether this fact improved the academic performance of our students. The original approach of this work consists in using psychometric tests to measure the degree of acquired student's generic competences instead of using opinion surveys, as usual. Results indicated that active learning methodologies improve the academic performance when compared to the traditional lecture/discussion method, according to the success rate obtained. These methods seem to have as well an effect on the teamwork competence (the perception of the behaviour of the other members in the group) but not on the perception of each students' behaviour. Active learning does not produce any significant change in the generic competence 'planning and time management'.

Keywords: active learning; cooperative learning; problem based learning; generic competence.

1. INTRODUCTION

ON APRIL 2009, the Ministers responsible for higher education in the 46 countries of the Bologna Process met to establish the priorities for the European Higher Education Area until 2020 [1]. They emphasized as well on the significance of student-centred 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]. Active learning methodologies such as Cooperative Learning (CL) and Problem Based Learning (PBL) are found among the approaches adopted in teaching and learning.

CL [3–5] is an instructional method that involves students to work in a team in order to reach a common goal. In this work, we have applied CL with the jigsaw technique [6]. The effectiveness of CL in higher education versus the lecture/discussion method has been examined in several studies [3, 7–10]. With regard to the possible relationship between CL and some generic competences development, the authors indicate in [11] that students remarked the specific skills developed with CL. These skills included working together without being too noisy, respecting one another, sharing ideas, negotiating in a problem solving process and also sharing their answers with the whole class. The authors based this study on interviews and questionnaires to students. They do not indicate the way they have valued the achievement of generic competences. They just mention students' opinion. In [12] the authors point out that 'In the present study, both teachers and students attributed academic and social benefits to working in a team. A total of 38 out of 46 students (83%) mentioned that CL helped them improve verbal and written communication skills. The survey (observation and questionnaire research) showed that as many as 41 (89%) students claimed to have developed not only some of the following social skills (problem solving, decision taking, conflict handling, negotiating, leading, delegating, listening, presentation making), which are necessary for their future work environment, but also personal qualities (high degree of motivation, enthusiasm, self-confidence, self-esteem, ambitiousness, responsibility, creativity)'.

PBL bases on problems as a primary determinant for learning. This implies a deductive reasoning process which is articulated by generating

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hypothesis, facts, issues, strategies and tactics that are checked as the students move through the problem [13]. Different studies have shown a higher effectiveness of PBL over the lecture/discussion method [14–18]. PBL also plays an important role in the development of teamwork and communication skills [19–24] besides other generic competences [25–26]. In [24] the aim is to determine the opinions of tutors and students about the effectiveness of Problem-Based Learning in Dokuz Eylul University School of Medicine. A questionnaire with five-point Likert scale rating PBL outcomes was administrated to tutors and students. The questionnaire covered opinions about how PBL facilitates some skills such as gaining clinical reasoning, problem solving, communication, self-directed learning, gaining robust knowledge, gaining basic and clinical science knowledge and increasing intrinsic motivation of students. The main results point out that tutors and students had a positive opinion about PBL's effectiveness, although the ratings for gaining basic science knowledge were the lowest. We should highlight that these two last studies try to obtain directly impressions of students. This way, students are asked directly if they think that PBL is helpful to enhance some skills, but the authors do not try to measure the skills observed in students. In [25] the authors, using a questionnaire, come to the conclusion that most students considered that PBL was effective in promoting the development of problem-solving and teamworking skills and in fostering some attitudes such as respect for other people's opinion

The Educative Innovation Group DMAE-DIA [27] of the Universidad Politécnica de Madrid has been using active learning methodologies such as CL and PBL [28–31] for several years. This group is aimed at: 1) achieving a more active participation of students in the learning/teaching process; 2) improving students' academic performance by promoting specific competences and 3) promoting the development of generic competences. Precisely, one of the objectives of the European Higher Education Area is helping students to develop generic competences in line with their degree. These competences will be used during their professional practice. Some of them belong more specifically to one degree, but others can be achieved in most of the profiles; for instance, 'Planning and time management' or 'teamwork'. The latter competences can be developed by carrying out different tasks of teaching/learning, which have also been designed for the development of specific competences. Nevertheless, some of the generic competences need specific training programs to address skill gaps during the degree.

In this work, we present the experience of applying CL and PBL to an Operating System course of 159 students. The study is aimed at evaluating the effect which these active learning methodologies have on: 1) the academic performance and 2) the development of certain generic competences, specifically primary strategies related to studying behaviour (planning and time management) and teamwork. As far as we are concerned, no studies of this nature, which evaluate with objective measurement instruments the effect which CL and PBL have on the development of the two aforementioned generic competences, have been published. Hence the importance of this study. Therefore, studies which tackle the amount of generic competences acquired using verified and scientifically validated instruments such as the ones introduced in the current paper are needed. Besides, it is necessary to specify the influence that active learning methodologies have on the achievement of the generic competences stated before. The fact that nowadays each university in the European Higher Education Area is defining the level of competences that their graduates must achieve should be taken into account. As a quality management element, every university needs to know the degree in which their graduates have reached that level. To this end, the following hypotheses were contrasted:

Hypothesis 1. The proportion of success achieved by the students who follow active learning methods like CL and PBL will be significantly greater than that of the students who follow the traditional lecture/discussion method.

Hypothesis 2. When active learning methods (CL and PBL) are applied, students show an increase (from the beginning to the end of the course) in the generic competences of primary strategies which are related to studying behaviour (planning and time management) and teamwork.

This paper is organized as follows. Section 2 indicates the number of participants who have taken part in the project, the teaching practice developed and the way in which specific and generic competences were acquired. Section 3 presents how data design and analysis were measured and the study results. Finally, in Sections 4 and 5 we present the main conclusions and some limitations of this project.

2. METHOD

2.1 Participants

This study was carried out during the 2007/2008 academic year. Operating System I subject is a compulsory course taught in the 3rd semester of the Technical School of Computer Science (Universidad Politécnica de Madrid). Of the 316 total students enrolled in the course, 159 students, divided in four groups, attended active learning classes (CL and PBL) and 157, divided in three groups, attended traditional lecture/discussion classes. The age of the participants ranges from 20 to 62. The number of students who were older than 30 years was 16 (10.1%), 34 students (21.4%)

were between 25 and 30 years, students under 25 added up 109 (68.5%). The average age was 24.61 years old. 87.4 % of students were male and 12.6% were female.

2.2 Procedure

OSI is divided into five topics: Introduction, Process and Threads, Memory Management, Input/Output and File Systems. Students only had one reference book [32] in order to meet the topics as well as two other additional reference books [33-34]. During the academic year 2007/08, the first two topics were taught using CL, while the rest used PBL. Courses were aimed at 1) ensuring that students could understand theoretical knowledge; and 2) providing them with abilities to deal with new problems related to the modern basic concepts of operating systems (practice application and operative knowledge). The course developed along 15 weeks. A two-hour session was held weekly. Besides, during five of these weeks there was a two-hour practice session. Apart from these 40 hours of class work, students should invest over 80 additional hours of individual or group work so as to solve the problems raised by the professor and to study the material. Four activities were developed along the course: Lab exercises, CL, PBL and Test, which will be described below.

Lab exercises. Students had to do five lab exercises related to the subject topics. They used several simulators [35] during lab sessions. These sessions were carried out implementing CL with a jigsaw technique. Each session lasted 110 minutes. The lab instructor divided students ad hoc into groups of four in every lab session. Students were assigned a group randomly. The number of groups varied from 5 to 7 depending on the session. The first lab session consisted in a training session, where the instructor showed students CL following a jigsaw technique by using a problem about POSIX (Portable Operating System Interface) system calls. Simulators were used during the following four sessions. The manual of the simulator was divided into four parts and a different part was assigned to each member of the group. The proposed experiment could only be solved if all of the members worked together and shared with the rest the individual knowledge acquired about the simulator. The instructor gave each member 15 minutes to read the assigned part of the manual. Later, all the members joined the other students who had been assigned the same part of the manual. Afterwards, they gathered again in groups of four people, which are called 'expert groups'. Students met for 10 minutes in order to discuss and clear up doubts. Then, all the students returned to the initial configuration. For 5 minutes, each expert in a group taught the other members about the information learned. After 20 minutes time, the instructor gave the groups the problem to be solved. It had to be solved within 40 minutes. The solution of the problem needs information from the four experts. The last 25 minutes of the session were used to discuss and debate.

CL. The CL unit, which covers topics 1 and 2, was made up of ten handouts (exercises). Among them, five had to be carried out individually and the rest (5) in the base group. Half of them (5) were done during class hours, while the other half were carried out after class. CL was implemented in each class and students were divided into groups of 4, referred to as base groups. The number of groups varied between 6 and a maximum of 9, depending on the classroom. These groups were not modified until the end of the course. Learning was carried out implementing CL with a jigsaw technique. For this activity, each member of the group had to prepare a topic of the syllabus after class hours, becoming this way an expert on that topic. Each expert task, explained in Moodle [36], consisted of studying certain concepts and solving problems related to them. The solution had to be submitted at the beginning of each class. Classes were divided into different phases. In the first phase, experts from the different groups who had been assigned the same topic got together so as to clear up doubts. During the second phase, the four members of each base group gathered and every expert explained to the rest of the group what he/she had learnt. Once every member knew about the topics which his/her mates had learnt, the whole group was handed in a problem to be solved using the knowledge they had acquired; this took place during the third phase. The group had to submit the solution before the end of the class. A small debate about the different solutions submitted was held during the final phase, moderated by the professor,

PBL. The PBL unit, which covers topics 3 to 5, was made up of 15 handouts. Nine of them were carried out individually and the rest (6) were done with the base group. Six out of the 15 handouts were carried out during class hours and the other nine were done after class. The solution of each problem was reached following five phases: (A) Connecting with the problem; in this phase, the context of the problem was introduced and the doubts reached after reading the wording were cleared up. (B) Establishing an action plan, phase in which each group prepares the strategy to be followed in order to solve the problem in the following phase. (C) Dealing with the solution. (D) Showing the results; students not only created the documentation needed but also defended their solution with an oral explanation during this phase. (E) Abstracting the knowledge, to which end students drawn up a conceptual map after each subject was finished, in which they included all the knowledge acquired when solving a problem. Students had to study the different subjects of the syllabus on their own. Afterwards, the group tackled the phases to solve the problem which had been raised by the professor. In some occasions,

phase A (Connecting with the problem) has been carried out in a debate held in the classroom, in which all the groups took part. A primary objective reached with the PBL methodology was that students could develop the skill to solve problems by themselves. For this, we started with complete case and teacher-directed problems progressing then to ill-structured and self-directed ones.

Test. Four tests were done during March, April and May. These tests were cumulative in the way that they covered the entire subject taught until the moment.

All the activities described before were assessed. The way how this assessment method took place is described in the next section. In addition, some questionnaires which evaluated two kinds of generic competences were completed both at the beginning and at the end of the course: primary strategies related to studying behaviour (planning and time management) and teamwork. In addition, at the end of the academic year, students responded to a survey of 21 questions, which was aimed at finding out the level of satisfaction reached by students with active learning methodologies (CL and PBL) and continuous assessment.

2.3 Measurements and instruments

Three different types of measurements were used: the ones corresponding to academic performance, those with regard to generic competences and the opinion survey answered by students.

Academic performance. A continuous assessment method was followed in order to evaluate the achievement of specific competences of the subject. As it is indicated above, the course was divided into four activity units, all of which can be evaluated: lab exercises, tests, CL and PBL. Every of the five lab exercises which students completed was assigned a maximum of four points (being 20 points the highest grade to be achieved). Four tests were done and each of them was assigned a maximum of 5 points (up to a total of 20 points). Each one of the 10 handouts submitted in the CL unit was assigned 2.5 points as a maximum (a total of 25 points). The 15 handouts of the PBL unit were assigned 35 points. In each handout, students provided information about the time spent completing it. Student final mark was made up of all the grades obtained in the four units (0-100). To pass the subject, the student had to obtain a minimum of 50 points, as well as at least a third of the total possible mark in each of the four units. A successful student is that who complies with these requirements.

Generic Competences.—The instruments used to measure the generic competences were two psychometric tests: Diagnóstico Integral del Estudio (DIE-3) [37] and Team Work Behaviour Questionnaire (TWBQ) [38]. DIE-3 was used to measure planning and time management competence, while TWBQ was used to measure teamwork competence. DIE-3 measures Primary Strategies (PS) related to studying behaviour of students. This test offers three scales of measuring. Scale 2, used in this work, is made up of twelve items with three possible answers each and assigns a total mark depending on the answer chosen. This scale measures different processes during the study, such as: pre-reading, marginal notes, highlighting, outlines, diagrams, conceptual maps, summaries and charts. Teamwork was evaluated according to a test which was created (TWBQ), which is based on twelve items used in [38]. Teamwork refers to the individual activities which contribute to team process. Interpersonal behaviours (conflict and problem solving, collaboration, communication) and management behaviours (assuming leadership, establishing goals, planning tasks, coordinating the other members in the group) are assessed. This test has two parts: one in which students have to assess their own ability, TWBQ (Self), and another in which they assess the ability of the group as a whole, TWBQ (Others). In each item (statement), participants have to evaluate their own behaviour or the other members' behaviour in terms of an appropriate behaviour, on a 7 points Likert-type scale (1= not at all; 7 = very much). The test gives each part a total grade.

Opinion surveys. Students responded a 21 question survey: 2 concerning the tests, 5 with regard to CL and PBL, 4 related to the assessment method and 10 in connection with other matters of the subject. Depending on the answer, students were assigned 1 to 5 point in each question. The questionnaire was responded by 113 students and was carried out during the penultimate week of the academic year.

3. DATA ANALYSIS AND RESULTS

To analyse the relationship between active learning methods (CL and PBL) versus traditional lecture/discussion method and the level of specific competences reached, comparisons concerning the level of academic success reached were carried out. A 'z-test' was employed. The effect of active learning on the generic competences considered here—primary strategies which are related to studying behaviour (planning and time management) and teamwork—was examined by comparing the mean obtained in each generic competence measured both before and after active learning methods were implemented. A 't-test' for related measurements was used. In all these comparisons, a significance level of 0.05 was used. Analyses were performed with the SPSS 15.0 statistical package [39].

An amount of 159 students were registered during the academic year 2007/08, which followed active learning methods. Among them, 125 students followed the continuous assessment until

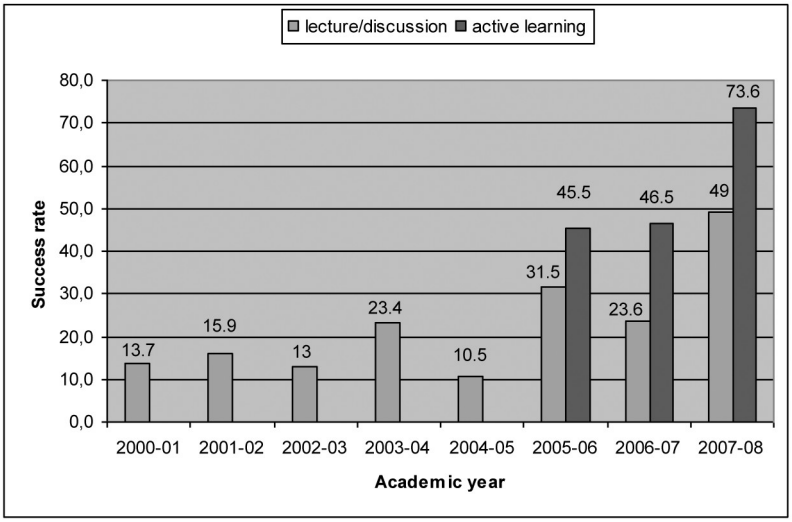

Fig. 1. Success rate by academic year.

the end of the course. Among these 125 students, 117 passed (success rate = 73.58%) and 8 failed. From the 157 students who followed the traditional lecture/discussion method, 77 students passed (success rate = 49.04%). The success rate was calculated as the quotient between the numbers of students who passed the subject and the total of registered students.

In order to put these results into context, Fig. 1 shows data (percentages) about the success rate obtained in the subject from the academic year 2000/01 to 2007/08. The introduction of active learning methods has been gradually carried out since 2005/06, but it has not been applied to all the OSI groups. This figure separates the results obtained with traditional lecture/discussion method from those obtained with active learning. Moreover, continuous assessment was slowly introduced since the academic year 2005/06 just to those groups which followed active learning. Finally, in the last academic year (2007/08) CL and PBL were introduced to active learning groups during the whole course. From 2005/06 to 2007/08 a tendency towards change in the students' success rate from all the groups—both when the lecture/discussion method was followed and when active learning methods were applied—has been observed.

To test hypothesis 1, the success rate achieved by the groups which followed active learning methods during the academic year 2007/08 (73.58%) and by the ones which followed the traditional lecture/discussion method (49.04 %) was compared. A statistically significant difference was found ($z = 4.5$, $p = 0.0000$). Thus, students following active learning methods present a higher success rate than those who follow a lecture/discussion method.

In order to analyze in great detail the mark assigned in the tasks carried out following CL and PBL, the average mark achieved was examined. Table 1 shows the mean and the standard deviation for both (CL and PBL) on a 10-point total scale in order to compare results.

Students in CL obtained a mean of 7.2 out of 10 (18 points out of the 25 from the original scale) and an average of 6.13 points out of 10 (21.4 points out of 35) in PBL. As an average, marks were 10% higher following CL than following PBL. The difference between the means of the two different assessment types turned out to be statistically significant ($t [120] = 7.953$, $p < 0.001$).

The means and standard deviations of the measurements of the generic competences which were carried out at the beginning and at the end of the course are shown in Table 2. In order to test hypothesis 2, the means obtained in the generic competences at the beginning and at the end of the course were compared. A statistically significant difference was not found when comparing PS (DIE-3) means at the beginning (13.41) and at the end of the course (13.51) ($t [78] = –0.277$, $p =$

Table 1. Mean and Standard Deviation (SD) in CL and PBL

Evaluation Type	Mean	SD
CL	7.21	1.35
PBL	6.13	1.17

Table 2. Mean and Standard Deviation (SD) in generic competences at the beginning and at the end of the course

Generic Competences	Beginning	End
	Mean (SD)	Mean (SD)
PS–(DIE-3) (Studying behaviour)	13.41 (3.719)	13.51 (4.260)
TWBQ (Self)	54.65 (12.501)	56.34 (13.566)
TWBQ (Others)	51.55 (11.085)	56.78 (11.657)

0.782). Both means are below the population mean of Spanish university students [20].

There was an increase of the TWBQ (Self) mean at the end of the course (56.34) in relation to that of the beginning (54.65). Nevertheless, this difference is not statistically significant (t [78] = –1.201, p = 0.233). A statistically significant difference was found between the TWBQ (Others) means at the beginning (51.55) and the end (56.78), (t [76] = –3.220, p = 0.002) of the academic year.

As in the comparison between TWBQ (Self) and TWBQ (Others), there was a statistically significant difference between both means obtained at the beginning (t [93] = –3.170, p = 0.002). However, at the end of the course this contrast disappeared (t [91] = –0.092, p = 0.927).

As far as the opinion surveys regarding the level of difficulty of the tests is concerned, it is important to note that 75.2% of the students considered the questions to be quite/very difficult. On the other hand, to the question 'In general, I think that CL and PBL methodologies have helped me understand and learn the concepts in depth', only 16 students (14.16%) quite/totally disagreed. Moreover, it is important to note that 68.16% of the students think that CL is an appropriate methodology in order to understand the subject, while 41.59% think the same about PBL. A total of 93.33% of the students surveyed considers the workload to be a lot or excessive regarding the amount of ECTS of the subject (4).

4. DISCUSSION

In general, the introduction of continuous assessment and active learning since the academic year 2005/06 has remarkably improved students' academic performance. The success rate achieved with active learning and continuous assessment in 2007/08 overcame in a 24.6 the rate achieved with the traditional lecture/discussion method. These results lead us to confirm the first hypothesis formulated and coincide with the findings of other authors in [3, 7–10, 14–18]. It should be pointed out that this increase in the success rate entails an increase in the amount of time which students dedicate to the subject (a generally observed fact when active learning methodologies are applied), as we can deduce from the information given by students in each handout. These results coincide as well with the information given by students in the survey, as we can see at the end of section 3. We should wonder if this level of success will be maintained when these kind of teaching/learning methodologies are applied to the rest of subjects. Students will have to make a greater effort from their current 30 weekly hours to 50 hours when new study plans come into effect in September 2010.

A detailed analysis about students' performance carried out in different tasks shows that the lower marks were obtained in the test unit. Students found the tests difficult, as we can tell from the surveys which they responded at the end of the course (although we have detected a slight improvement in the two last academic years). The general opinion about the level of these tasks is the same as the one obtained when traditional learning methodologies are applied. These difficulties and the low performance could be related to the low level reached in the Primary Strategies, which are connected with study behaviour measurements in (DIE-3) [37].

Results regarding study behaviour—more specifically, with concern to primary strategies—show a level which is lower that the one in the normative group they belong to. No differences between the beginning and end of the course were found. Both means (at the beginning and end) are below the population mean for Spanish university students [37]. This suggests that the strategies followed by our students should improve in order to organise better their study habits and perform consequently at a higher level on the tests which assess the knowledge acquired and the specific competences of the subject. A possible way of achieving this improvement would be to instil this aspect into students' habits.

As far as students' perception of their ability to work in a group is concerned, the results of the TWBQ (means and standard deviations) coincide with the means and the standard deviation obtained by other authors in similar tests [38]. An improvement in the perception of individual and group ability is observed from the beginning of the course to the end. Although this improvement is not statistically significant for TWQB (Self), it is for TWQB (Others). Consequently, it would seem that after working with CL and PBL, students consider their classmates to be more able to work in a team, but there is no change in the perception of their own capability. It should be noted that in this study, the ability to work in a group at an individual—not group—level has been evaluated, taking into consideration the opinion of the different members of the group [40–41]. Otherwise, the comparisons between TWBQ (Self) and TWBQ (Others) made at the beginning and end of the course suggest that at first, students consider themselves more capable of working in group than their classmates, but this difference disappears at the end of the course, when they see their classmates as capable as well. This information allows us to partially confirm hypothesis 2, in which significant differences in the TWBQ (Others) between the beginning and end of the course were observed, but not between the means in the TWBQ (Self). On the other hand, no difference between the two means (beginning and end) was detected for studying behaviour.

Finally, it is worth explaining the academic performance variations observed when applying the lecture/discussion model from 2004–05 to 2007–08. In the lecture/discussion methodology, the assessment is based on a final exam which

covers most of the final mark. This written test consists of two parts: a theory test and the resolution of two complex problems. Although the theory parts produce more or less constant results along the years, we have observed that there are great differences in the results obtained from problems resolution depending on the difficulty of the problems given to the students each year. A small variation on the difficulty of problems can produce great variation on the results obtained by students. This fact explains the variations from year to year in the results of lecture/discussions that are especially significant in the last year. Furthermore, it represents an important drawback of the final evaluation if we compare it with continuous assessment.

5. CONCLUSIONS

The results obtained both in the average marks and in the survey responded by students show that students work better with CL than with PBL, as it is indicated in section 3. This difference is supposed to be due to the level of maturity of students. PBL begins with complete case and teacher-directed problems and extends to ill-structured and self-directed ones. From the first level of PBL it can be detected that students find serious problems when it comes to dealing with the exercises. This methodology is probably more suitable in a final-year class than during the second course. A reason for this greater performance with CL and the jigsaw technique could be that this methodology guides students in a better way: it indicates them what and how to study, as well as the intensity of study (the amount of hours).

We find several reasons that can explain the results of the low differences observed in TWBQ tests. First, a semester may be a very short time between the measures before and after using the methodologies. Second, it is possible that the methodologies alone do not improve the generic competences that we studied. We conclude that students need some specific preparation on 'study techniques' and 'team work' before using them for active learning methodologies. Finally, more study time of the group work would be required in order to find more significant changes in the individual perception of teamwork competence. In the next years, we will study the possibility of including some seminars to guide students in the development of generic competences. Besides, we will program the competence measures to see students' progress along several years.

With regard to the objectives proposed, one limitation of this project is that the participants are university students of the Technical School of Computer Science and therefore they do not constitute a representative sample of the population of university students. That is why the results obtained should be interpreted within this context. On the other hand, learning methods were not assigned randomly to the groups. These factors should be taken into account in a future research. Concerning teamwork competence, students' perceptions should be related to the observed behaviour in class and the efficiency when solving problems [40] in a future research.

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