International Journal of Engineering Education Vol. 30, No. 6(B), pp. 1729–1740, 2014
Printed in Great Britain

0949-149X/91 $3.00+0.00

Do Classes in Cooperative Classrooms Have a Positive Influence on Creativity and Teamwork Skills for Engineering Students?*

RAQUEL MARTÍNEZ
Dept. Automática, Ingeniería Electrónica e Informática Industrial—Universidad Politécnica de Madrid. C/ José Gutiérrez Abascal, 2-28006, Madrid, Spain. E-mail: raquelm@etsii.upm.es

CAMINO GONZÁLEZ
Dept. I. de Organización, Administración de Empresas y Estadística, Spain.

PASCUAL CAMPOY
Dept. Automática, Ingeniería Electrónica e Informática Industrial, Spain.

ÁLVARO GARCIA-SÁNCHEZ and MIGUEL ORTEGA-MIER
Dept. I. de Organización, Administración de Empresas y Estadística, Spain.

Contributing to the acquisition of professional creativity and teamwork skills has been a special challenge for some of the subjects taught at the Technical University of Madrid (UPM), and this has been a starting point for the work described in this paper. Some professors have intuited that the use of cooperative classrooms could facilitate the acquisition of these skills. We describe the new methodologies applied within cooperative classrooms by some professors, and present the procedure for measuring students' perception of their own learning outcomes, skill improvements, and overall satisfaction with the use of this kind of classroom. For this project, 250 students enrolled in several subjects answered a questionnaire. The features of the subjects involved in the project are widely disparate. We present the results of the statistical analysis with special emphasis on creativity and teamwork skills, and we conclude that the use of cooperative classroom has a positive influence on the acquisition of these skills. This work has the added value of being the first analysis of student perception of the use of cooperative classroom in the acquisition of creativity and teamwork skills.

Keywords: creativity; teamwork; new methodology; public speaking

1. Introduction

In this section we begin by analyzing the status of the acquisition of generic creativity and teamwork skills and the results that have been obtained in various studies. It also describes the impetus and motivation behind the UPM teachers who have relied on the use of cooperative classrooms to reinforce the acquisition of these skills.

There is some discontent with traditional engineering methodology; many engineering faculties continue to focus narrowly on the science of engineering, without taking into account the development of other capacities. Rogers [1], referring not only to engineers, believes that "unless man can make new and original adaptations to his environment as rapidly as his science can change the environment, our culture will perish". Pappas [2] writes "engineering is, by nature, a creative endeavor, but many engineering colleges fail to address this, and end up training engineers for technological task completion". A lot of teachers advocate the need for a 'renaissance' engineer who is a creative thinker [3]. Creative engineers should be able to explore and scrutinize the available data or information and generate novel solutions to specific engineering problems or for the production of a unique product [4].

Similar thoughts pertain to teamwork, because there will be few engineers that could work isolated so the taxonomies of engineering skills include teamwork as a required core competency (e.g. CDIO at MIT) [5]. There are some interesting works in the literature about creativity and teamwork. For example, on creativity, Felder [6] proposes some techniques to help engineering students develop creative thinking skills; Johri [7] examines the role of computers in supporting creative collaborative engineering design; Bjørner [8] presents case study results from Medialogy, a cross-disciplinary educational methodology taught at Aalborg University; and Zhou [9] presents a study exploring the link between project-organized learning and group creativity.

Many papers in the literature are about teamwork: Parkinson [10] reviews some of the efforts taking place at universities in the U.S. with global virtual teams (geographically dispersed, spanning

* Accepted 15 July 2014.

several different countries and time zones); Ball [11] examines the results of an international team-based operations management assignment between two universities; Lau [12] examines the role of diversity in design team performance and discusses how diversity factors affect the dynamics and success of a design team; and Hirsch and McKenna [3] investigate various pedagogical approaches to combining teamwork experience with reflective activities to help students learn.

Engineering education in the Spanish University has undergone a deep change over the past five years. The factors that account for this change are many, the most important being the need to converge towards the European Higher Education Area (EHEA) [13], the emergence of new Bologna guidelines [14] and the requirement to complete the training of graduates in not only technical but also professional skills. ABET (Accreditation Board for Engineering and Technology) accreditation [15] has underscored the importance of training in generic or transversal skills in the UPM. Teamwork and creativity are now considered skills that an engineer must acquire.

Within the new European Higher Education framework, education is focused on the student and his/her personal effort in the acquisition of concepts and skills. Professors have had to change their evaluation methods because it is not enough to carry out a final assessment of concepts in each subject. On the contrary they must facilitate, on one hand, a progressive knowledge acquisition and, on the other, a continuous assessment of it.

This revolution has led to a transformation of how to learn and therefore how to teach. Generally, technical university professors are not experts in educational techniques; they have had to make a considerable effort to phase out the traditional classroom lecture methodology and adopt a new training methodology, more active, interactive and collaborative. Students also have had to adapt to a new, more kinesthetic and visual way of learning [16]. In order to achieve success in this type of education, it has been essential to use new technologies and to adapt the infrastructure of classrooms so that students can work in groups to solve problems, fostering innovation and creative solutions.

In that sense, during the academic year 2005–06, the Industrial Engineering School (ETSII) at UPM decided to initiate a new methodology for teaching in order to modernize and improve academic performance and student learning. ETSII-UPM contacted the SCALE-UP (Student-Centered Active Learning Environment with Upside-down Pedagogies) initiative [17]. SCALE-UP promotes a new teaching methodology based on infrastructures adapted to teamwork in classes. The main idea is that students are provided with something interesting to investigate. While they work in teams, the instructor is free to roam around the classroom, helping students and conducting the class, as well as observing student skills first-hand. The first step was equipping two classrooms with a set of computers connected by an intranet, one of which is used by the professor. Student tables are round with nine seats and three computers because this structure facilitates, preferentially (but not exclusively), working in groups of three students. All computers have Internet access and can operate using the Windows XP operating system or Linux (Ubuntu). Classrooms also have two projectors and screens to allow viewing the screens of both the professor's computer and any of the computers used by the students. This is possible through software platforms such as VNC (Virtual Network Computing). The initial objective is that the method of discussion and group work, facilitated by these classrooms, complement traditional education, allowing a different perspective and more comprehensive student training.

Cooperative classrooms have been successfully used in ETSII-UPM since 2005 for teaching subjects leading toward engineering and master degrees by a small number of professors, but it was during the academic year 2010–11 that teachers using these classrooms began to intuit how cooperative classes encourage the creativity of students and, of course, teamwork. For that reason we decide to analyze student perception of the acquisition of the two skills analyzed in this paper:

- d-ABET: an ability to function in multidisciplinary teams.
- UPM competency: creativity.

This paper is structured in four sections. In second, we describe the UPM subjects that were taught as part of this project, their intrinsic characteristics and their inherent problems in acquiring learning concepts and generic skills. It also explains some teaching methods applied in cooperative classes with the aim of solving the above-mentioned problems. Due to space limitations, we explain the methodology of only a selection of subjects involved in this analysis. At the end of this second section, we present the procedure followed in analyzing student and professor perceptions of the use of new classrooms and associated methodology. In order to analyze how students perceive the use of cooperative classroom in the acquisition of creativity and teamwork skills, we designed a questionnaire that has been filled out by 250 students. The statistical analysis of results is presented in the third section, along with the impact on student acquisition level of creativity, teamwork and public speaking skills.

Finally, in the fourth and fifth sections, we describe some future issues and draw conclusions from this experience.

2. Teaching-learning methodology

The context of this work is a public institution: ETSII at UPM. There are two important features to consider in the analysis of the results: the diversity of the subjects involved and the type of students taking these subjects. It should be noted that not all teachers have followed specific paths in promoting creativity. This work has the added value of being the first analysis of how students perceive the use of cooperative classroom in the acquisition of creativity and teamwork skills.

This study refers to students of a wide range of subjects (Table 1) with differing characteristics:

1. Corresponding to several degrees, such as engineering, bachelor and master degrees;
2. In different years, from the first to the fifth;
3. Encompassing obligatory, core and optional subjects;
4. With different student numbers in the classroom, ranging from 20 to 120.

Some of these subjects are: State Space Control (SSC), Mathematical Methods (MM), Introduction to Programming (IP), Simulation for Designing and Operating Logistics Systems (SDOSL), Nuclear Reactor Design (NRD), and System Programming (SP). For each subject, the number of classes taught in cooperative classrooms varies; some subjects use the classrooms for all classes, while other subjects only use them for a small number of classes that are more suited to this type of classroom. For some subjects, we describe specific features, skill objectives, problems in achieving them, and intended solutions using the methodology based on cooperatives classrooms. The learning methodology is different for every subject since there are many differences between them.

Introduction to Programming (IP) is taught in the first year programme of two (Industrial Technologies and Chemical) engineering bachelors. The subject is obligatory for 450 first year students, distributed among classes of at least 80 students. This is a very high number, and it is impossible to use a classroom with 80 computers to introduce the use of software tools. This course is also engineering students' first contact with computer programming, since none of them have programmed or used compilers or integrated development environments (IDEs). This is a very difficult technological barrier to overcome individually and, as we verified at the end of the academic year, many students abandon programming because of it. Besides, during the course, the two generic skills of creativity and teamwork must be developed. Cooperative classrooms could be a very good tool for reaching these objectives and solving the problem described above. We summarize the learning methodology as follows: the professor forms groups of three students working together to write a C-program with the IDE. The program is very simple but with some errors. Using the IDE and also a compiler, the students struggle together against problems and find the errors in the program, correct the mistakes, using Internet or asking the teacher's help. The result is very satisfactory for both students and teacher. Students realize that it is very easy to learn programming in a group, each student giving his or her opinion about how to correct the program and learning from the new ideas and knowledge of his or her colleagues. Students feel less alone at the outset of programming training. We have seen that this learning method helps students lose their fear of dealing with IDEs and compilers, and they can continue programming alone at home.

The Simulation for Designing and Managing Logistics Systems (SDOSL) course is taken in the

Table 1. Type of subject involved on the study

Subject	Official Degree	Type	course	# students
Mathematical Methods	Industrial Engineering	Obligatory	4	39
Introduction to Programming	Bachelor on Industrial Engineering Technologies	Obligatory	1	72
Simulation for Designing and Manage Logistics Systems	Industrial Engineering Master	Elective	4–5	15
System Programming	Bachelor on Industrial Engineering Technologies	Track	3	71
Nuclear Reactors Design	Industrial Engineering Master	Track	5	26
State Space Control	Industrial Engineering	Track	4	29

fourth or fifth semester. It is an elective course designed for students of the Organization (Industrial Engineering) specialty. In this course we teach discrete event simulation theory complementary to knowledge acquired in previous courses. Although the main objective is to learn the content itself, promoting general student skills acquisition is also important. During the course, oral communication and teamwork skills must also be developed.

We work with a reduced group of 15–20 students divided into groups of three or four. After students individually learn concepts and acquire practice, each group is offered an industrial problem in which discrete event simulation is needed. Every group plays two roles, client and supplier client and supplier, as shown in Fig. 1. For example, group A plays the role of the client with a problem which they have to present to group B, who plays the supplier role and provides group A with a satisfactory solution for their problem. Similarly, group A has to provide group B with a solution to a different problem Sessions are organized so that groups spend time both preparing and presenting their problems to their respective suppliers or understanding and solving their customer's problem. The skills of creativity (in solving quasi-real problems), teamwork (group discussion of approaches to the problem) and public speaking (preparing and delivering presentations to their clients or suppliers) are used, and the cooperative classroom (flexible room with the opportunity to work in teams) is a good aid in improving these skills.

Mathematical Methods (MM) is taught in the seventh semester of the Industrial Engineering degree in the Chemical and Material tracks and also in the Chemical Engineering degree. This subject incorporates both mathematical and statistical contents. Concerning statistics contents it can be considered as an advanced statistical experimental design course, and here learning methodology based on teamwork has been applied. The subject is obligatory for the students enrolled in previously

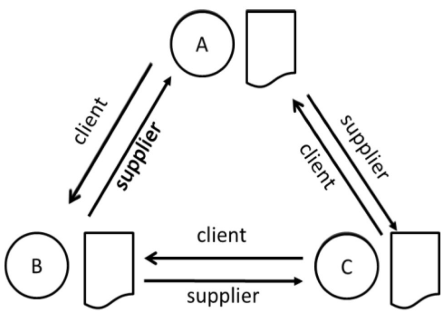


Fig. 1. Each of the three groups takes on the roles of client and supplier. For example, group A has a problem and needs B group to solve it, while at the same time trying to solve group C's problem.

mentioned tracks. During last four years, we have experienced an increase in the number of students from 30 to 55.

Students in the fourth year have a good mathematics and statistics background, but they still have some difficulties when required to apply their knowledge of uncertainty to real world phenomena. Therefore, we have found that teamwork methodology and the use of cooperative classroom are essential for students to acquire the required background and knowledge to face real world uncertainty problems. Besides, creativity is also needed to solve some of the tasks in the course, although this is not included in the syllabus as a primary goal.

We have been working with this methodology since 2005, and have perceived a positive change in student attitude. The problems which arose in implementing the methodology have been solved taking student feedback into account.

The course is organized as follows: students work in groups of three or four. Each team must solve seven tasks: five main problems, the analysis and peer review of a scientific article related to some specific items of relevance to the subject, and a project, which involves design, experimentation and statistical analysis of results. Different environments are used during the course. A traditional classroom is used to explain the problems and theoretical concepts. The rest of the time students work in collaborative classrooms discussing and finding solutions. During the completion of each task, a continuous assessment and feedback process is designed for each group to guide student learning. This is crucial for knowing if the solution has been achieved by consensus and evaluating the work of students as individuals and as team members. Both are necessary.

Space State Control (SSC) is taught as a compulsory subject in the seventh semester of the Automatics and Electronics specialty of the Industrial Engineering degree. The course is divided into 22 sessions of two hours each. A normal session is divided between a one-hour lecture (including examples) and another hour given to students, grouped in teams of three with a computer and using Simulink ©Matlab, for the solution of a practical exercise. These exercises are previously available to the students on the course website, as is the content of the lectures. A significant part of each exercise is solved in the classroom through collaboration within and between the teams. The professor roams in the classroom, solving difficulties for individual teams and, very occasionally, for all teams at once. This methodology encourages active student participation in solving the practical assignments of the course, as well as stimulating teamwork. Professor time can be invested in solving the real difficulties encountered by individual students and getting live feedback on the learning procedure, both globally and individually. Apart from these normal sessions, there are two special sessions for homework presentations and another three for individual exams. Each of the two homework assignments tackles several issues within a practical problem. These assignments are solved in teams (not related to occasional classroom teams) and presented randomly in these sessions. These presentations are judged anonymously by all the students using the course website, and the professor judges the related written documentation. These homework assignments promote teamwork in solving a global problem involving several aspects of the subject. Final student evaluation takes into account the teamwork homework assignments (30%), individual exams based on classroom exercises (50%); classroom exercises themselves (10%) and a freely assigned mark for participation in the classroom (10%)

2.1 Evaluating teacher and student experience

We performed an analysis of the experience and the results from the point of view of both professors and students. In order to use the cooperative classrooms, the teachers have to design and document new tasks for the students in the classrooms, with no resemblance to traditional practices, by taking into account the new teaching methodology. Professors must also learn the management software installed in these rooms and students must learn how to work in these classrooms and control specific provided software. In this paper we evaluate this experience from the point of view of teachers and students, learning from the mistakes and successes of these years. For this propose, two questionnaires have been developed and implemented.

- The first questionnaire evaluates the use of classrooms by professors. This questionnaire contains open questions for qualitatively evaluating the use of classrooms by teachers, requesting a mark from 0 to 10 from the teacher.
- A second questionnaire (Table 2) has also been developed for students. The questionnaire has 21 assertive questions that must be evaluated on a scale of 0-5 (0 = Non agreement, 5 = Absolute agreement), with the additional choice of "Don't know". These questions were grouped initially in four areas of assessment: *learning outcomes* (Q1–Q5), *competency results* (Q6–Q10) (teamwork and creativity), *satisfaction* (Q11–Q15) and *implementation* (Q16–Q21). There are also three open questions related to the infrastructure of the classroom, installed software and teaching methodology.

3. Main results. Actual benefits

The results of surveys among the students (250 students belonging to six different subjects answered the survey) have been statistically analyzed using univariate and multivariate techniques. The results are provided globally or subject by subject. Finally a satisfaction indicator has been devised.

The main focus of the statistical analysis is on the questions related to creativity and the ability to function on multidisciplinary teams, both of which are explicitly included in the survey. Additionally the analysis allows us to identify and assess how students perceive the teaching/learning methodology implemented in the collaborative classroom, in order to improve their conceptual understanding and quantify the effect of features related to their satisfaction.

3.1 Descriptive statistics

The paper mainly presents analysis results of the first three areas, since the last measures student perception of class infrastructure, its not a teacher dependent aspect. In fact, these questions have been included in order to evaluate the level of student satisfaction with regards to the institutional effort at classroom rehabilitation.

Initially, the primary features of the full set of data are described; afterwards, the results are stratified (categorized) by subject. Finally, correlation between the three first areas is evaluated and a satisfaction indicator is built.

Table 2. Student questionnaire

Learning outcomes
Q1. I learn much more during class time
Q2. I take advantage of my time better when I study at home
Q3. My practical assignments are better
Q4. My conceptual understanding is better
Q5. Globally I prepare myself better for the exam
Competency
Q6. It promotes student-professor communication
Q7. It promotes relationships with my companions
Q8. It promotes my creativity
Q9. It promotes my teamwork skills
Q10. It promotes my public speaking
Satisfaction
Q11. I like the teaching methodology
Q12. I like the organization of class time
Q13. My time is more active in class
Q14. My time in class is more fun
Q15. I would take another class using this methodology
Implementation
Q16. The classroom design is suitable
Q17. The software installed in classroom is suitable
Q18. The classroom infrastructure is adequate
Q19. The lighting in the room is adequate
Q20. The classroom climate is suitable
Q21. Information about the software is suitable

3.1.1 Learning outcomes

This area gathers student perception of how the new methodology used in the cooperative classroom affects subject learning. This area has five questions (Q1–Q5), of which Q4 ("My conceptual understanding is better") and Q5 ("Globally I prepare myself better for the exam") can be considered a summary since they express the influence of the methodology on the conceptual understanding of the subject and its utility in preparing the scheduled exams for each subject.

Presented in Table 3 is the number of students answering each question (count), central tendency estimates (mean and median), dispersion estimate (standard deviation) and the frequency distribution table for each question.

In this part, Q4 and Q5 summarize Outcomes learning. It can be seen that 61.47% and 56.48% of the students assign a score of 4 or 5 to Q4 and Q5 respectively. This reveals and confirms that students consider that the methodology is very important for improving conceptual understanding and for better exam preparation.

Thus, the first conclusion is reached: teaching learning methodology has a positive influence in acquiring knowledge and practicing to pass exams; i.e., in improving general student performance.

As each subject has a different degree of difficulty and the exams also differ in format, analysis by subject is very useful, the influence of methodology in both knowledge acquisition and exam preparation differing as well. Fig. 2 and Fig. 3 show 95% confidence intervals for the mean of the six subjects. It is worth mentioning that the different amplitude of intervals for each subject is the result of different standard deviation and the number of students enrolled in each subject. This number appears in parenthesis in the legend of the figures.

These results can be interpreted as in the following example. Students enrolled in Introduction to Programming (IP) consider that methodology is important in both aspects evaluated in Q4 and Q5. However, students enrolled in System Programming consider the methodology better for acquiring knowledge than for preparing for exams. In any case, all the means are higher than 3, so the students have a high opinion of the methodology.

Through the analysis of Q4 and Q5 we have a picture of the influence of the methodology on global student performance.

3.1.2 Competency

Here the students give their opinion on how the methodology promotes the acquisition of the creativity (Q8) and teamwork (Q9) skills. This is the main objective of the study described in this paper.

Some other questions are included in this part to complement the analysis. For instance, some subjects include in their program such other skills as

Table 3. Univariate descriptive of the questions belonging to part 1 of the survey: Learning results.

Outcomes Learning

Question	Count	Mean	Median	Standard deviation	0 (%)	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)
Q1	248	3.52	4.0	1.13	1.61	4.03	10.08	28.63	36.29	19.35
Q2	237	3.03	3.0	1.21	1.27	8.44	24.89	30.38	21.10	13.92
Q3	241	3.70	4.0	1.06	1.24	1.24	10.37	24.07	39.42	23.65
Q4	244	3.56	4.0	1.09	0.82	1.64	9.43	26.64	42.62	18.85
Q5	239	3.41	4.0	1.11	0.84	1.67	10.46	30.54	39.33	17.15

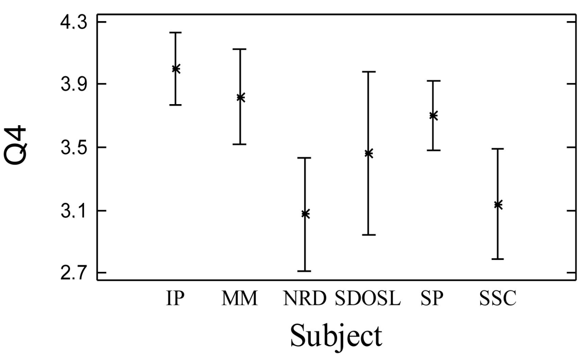


Fig. 2. Means and 95% confidence interval for Q4 ("My conceptual understanding is better"), stratified by subject. IP(66), SDOSL(13), SP(70), MM(39), SSC(29), NRD(27).

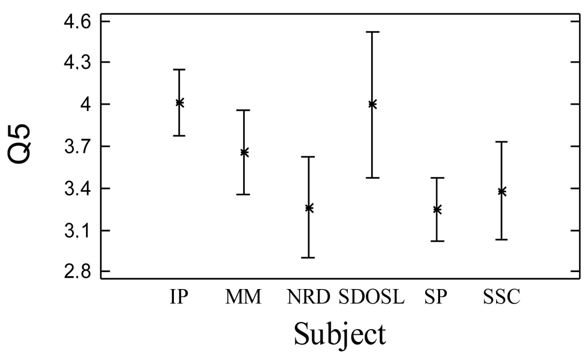


Fig. 3. Means and 95% confidence interval for Q5 ("Globally I prepare myself better for the exam"), stratified by subject. IP(63), SDOSL(13), SP(69), MM(38), SSC(29), NRD(27).

Table 4. Univariate descriptive of the questions belonging to part 2 of the survey: Competency results

Competency results										
Question	**Count**	**Mean**	**Median**	**Standard Deviation**	**0 (%)**	**1 (%)**	**2 (%)**	**3 (%)**	**4 (%)**	**5 (%)**
Q6	245	3.72	4.0	1.10	1.63	2.04	8.98	22.45	39.59	25.31
Q7	250	4.11	4.0	0.92	0.40	1.20	3.20	16.80	39.20	39.20
Q8	249	3.53	4.0	1.05	0.80	2.01	12.85	30.52	34.94	18.88
Q9	249	4.03	4.0	0.91	0	1.61	6.02	18.07	40.96	33.33
Q10	236	2.77	3.0	1.39	7.63	9.75	23.73	27.54	19.49	11.86

public speaking, so a specific question for this skill is included (Q10).

As for part 1, Table 4 summarizes central tendency and dispersion estimates as well as the frequency distribution table for each question in this part.

Results clearly indicate that students give very high scores to creativity and teamwork skills: 134 students out of 249 assign a score of 4 or 5 to creativity (54%) and 185 out of 249 a score of 4 or 5 to teamwork (74%).

Public speaking scores are more evenly distributed, with a lower mean.

Clearly the use of the collaborative classroom is essential in promoting teamwork skills, and also creativity (with a slightly lower mean). These results are logical because teamwork skills appear in the syllabi of all the analyzed subjects, while creativity appears in only some, and public speaking just appears in SDOSL and SSC.

Again, an analysis stratified by subject is worthwhile, and the 95% confidence intervals are given in Figs. 4, 5 and 6 respectively.

Some specific comments can be summarized. For instance, mathematical methods students feel that the methodology promotes the teamwork skill to a high degree, creativity to a lower extent, and public speaking not at all. This is in agreement with the subject objectives, in which only teamwork skills explicitly appear. However, as a result of the teaching/learning methodology and the tasks proposed in the course, the students develop creativity skills as well.

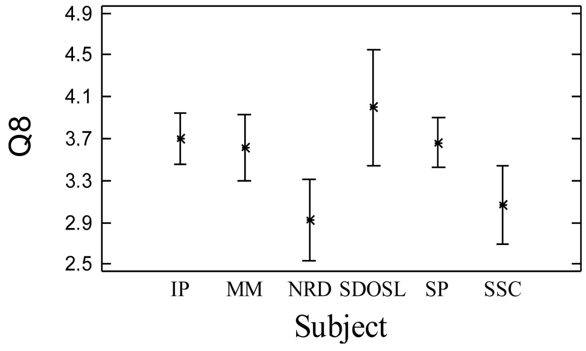


Fig. 4. Means and 95% confidence interval for Q8 ("It promotes my creativity"), stratified by subject. IP(70), SDOSL(13), SP(71), MM(39), SSC(29), NRD(27).

3.1.3 Satisfaction

The third part of survey concerns student satisfaction with the teaching/learning methodology. Here, questions Q11 ("I like the teaching methodology") and Q15 ("I would take a course using this methodology again") can be considered as global satisfaction indicators. As previously, Table 5 summarizes statistical information.

From the results it is clear that students are highly satisfied with the methodology (63% give a score of 4 or 5 to Q11) and 72.44% would repeat the experience.

The results, when stratified by subject, reveal different patterns as can be seen in Figs. 7 and 8.

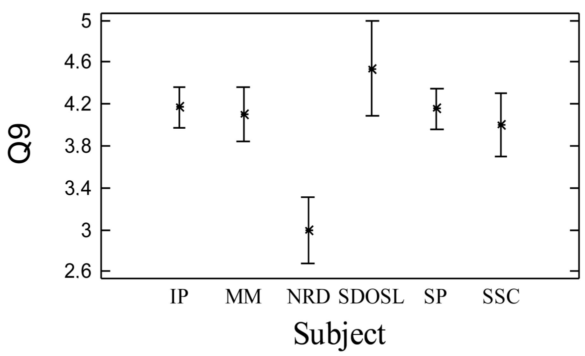


Fig. 5. Means and 95% confidence interval for Q9 ("It promotes my teamwork skills"), stratified by subject. IP(70), SDOSL(13), SP(71), MM(39), SSC(29), NRD(27).

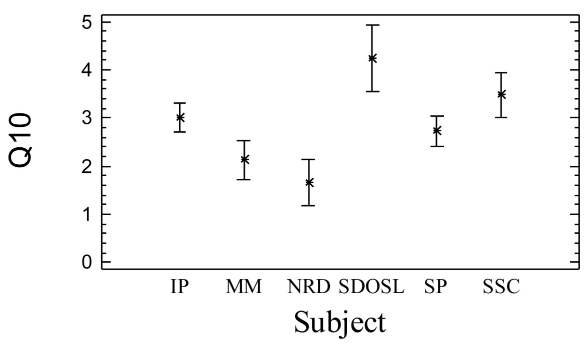


Fig. 6. Means and 95% confidence interval for Q10 ("It promotes my public speaking"), stratified by subject. IP(65), SDOSL(13), SP(66), MM(37), SSC(29), NRD(26).

Table 5. Univariate descriptive of the questions belonging to part 3 of the survey: Satisfaction.

Satisfaction										
Question	**Counts**	**Mean**	**Median**	**Standard Deviation**	**0 (%)**	**1 (%)**	**2 (%)**	**3 (%)**	**4 (%)**	**5 (%)**
Q11	249	3.76	4.0	1.00	0.80	1.61	7.63	24.10	42.17	23.69
Q12	248	3.56	4.0	1.07	0.80	2.82	12.90	25.00	39.92	18.55
Q13	247	3.62	4.0	1.11	1.21	2.02	11.34	29.15	31.17	25.10
Q14	239	3.87	4.0	1.16	2.09	3.35	5.44	17.57	37.66	33.89
Q15	238	3.99	4.0	1.07	2.10	0.42	5.88	16.81	37.82	36.97

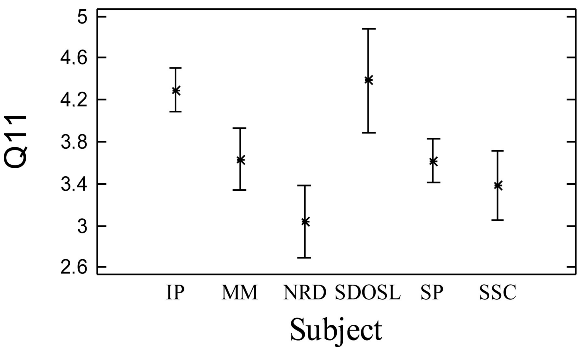


Fig. 7. Means and 95% confidence interval for Q11 ("I like the teaching methodology"), stratified by subject. IP(71), SDOSL(13), SP(71), MM(38), SSC(29), NRD(27).

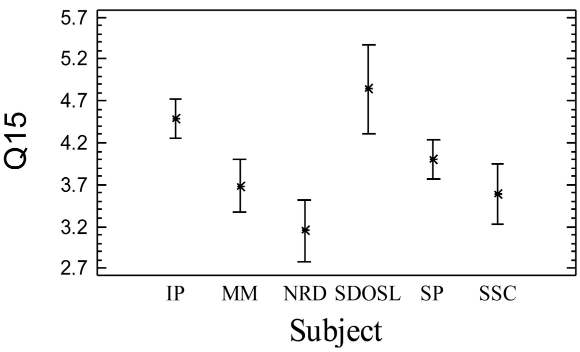


Fig. 8. Means and 95% confidence interval for Q15 ("I would take another class using this methodology"), stratified by subject. IP(67), SDOSL(13), SP(64), MM(38), SSC(29), NRD(27).

The final part of the survey refers to *Implementation,* which includes the infrastructural aspect of the collaborative classroom, light, climate, and software. Globally the results show that students are satisfied with the environment. For the sake of brevity, these results are not included here.

3.2 Multivariate Analysis

From previous analysis it is clear that students give high scores to the acquisition of creativity and teamwork skills from classes in cooperative classrooms.

Now, learning and satisfaction are analyzed through a multivariate analysis relation between skills.

First, we identify those features most highly correlated with creativity and teamwork skills. Afterwards, public speaking is also analyzed.

Table 6 provides correlation between creativity (Q8) and the other questions. The number of students involved in each correlation is in parentheses.

The highest correlations appears in teamwork skills, Q9 ($r_{8.9} = 0.5014$) and Q15 ($r_{8.15} = 0.4292$). It must be noted that creativity is also highly correlated to Q14 ($r_{8.14} = 0.4015$) and Q11 ($r_{8.11} = 0.3719$). All the correlations are statistically significant, with the exception of the correlation with Q2.

The conclusions are thus very satisfactory. Students give very high scores to creativity (previous section). These scores are highly related to teamwork skills and with the possibility of repeating with the methodology. Besides, the students enjoy the class. It can therefore be concluded that classes in cooperative classrooms have a positive influence on creativity.

Similar analysis can be performed for teamwork skills. Table 7 provides correlation between the teamwork skills (Q9) and the others.

The correlation pattern is quite similar to those obtained for Q8: The highest correlations appear with creativity ($r_{9.8} = 0.5014$), Q15 ($r_{9.15} = 0.4852$) and with Q14 ($r_{9.14} = 0.4085$). All the correlations are statistically significant with the exception of the correlation with Q2.

Similar conclusions to those previously outlined can be established. Teamwork skills and creativity are highly correlated, and classes in cooperative classrooms have a positive influence on teamwork skills.

The correlation of creativity and teamwork skills with Learning outcomes (Q1–Q5) are not as high as the others, but globally the acquisition of these skills is more strongly related to the improvement of conceptual understanding ($r_{8.4} = 0.3544$ and $r_{9.4} = 0.3255$) than to better exam preparation ($r_{8.5} = 0.3248$ and $r_{9.5} = 0.2784$). However, these are clearly subject dependent, which is why a correlation study stratified by subject is performed. Only the most relevant results will be presented here.

For instance, in IP both skills are more strongly

Table 6. Correlation between Creativity and the rest of questions. (*) Implies statistically significant correlation

	Q1	Q2	Q3	Q4	Q5	Q6	Q7
r	0.2172* (247)	0.0223 (236)	0.3460* (240)	0.3544* (244)	0.3248* (238)	0.3314* (244)	0.3675* (249)
	Q9	**Q10**	**Q11**	**Q12**	**Q13**	**Q14**	**Q15**
	0.5014* (248)	0.3066* (236)	**0.3719*** (248)	0.3213* (247)	0.3391* (246)	0.4015* (248)	**0.4292*** (237)

Table 7. Correlation between Teamwork competency and the rest of questions. (*) Implies statistically significant correlation

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
r	0.2782* (247)	0.0143 (236)	0.3733* (240)	0.3255* (243)	0.2784* (238)	0.3531* (244)	0.4197* (249)	**0.5014*** (248)
		Q10	**Q11**	**Q12**	**Q13**	**Q14**	**Q15**	
		0.3609* (235)	0.3370* (248)	0.2972* (247)	0.3621* (246)	0.4085* (238)	**0.4852*** (237)	

related to Q5, a very satisfactory result since this was precisely one of the reasons to implement the methodology in this subject. The same happens in SSC. However, for DNR and SP both skills are more strongly related to Q4 (conceptual understanding) than to Q5 (exam preparation). For MM, creativity is more strongly related to improvement in conceptual understanding, and teamwork skills are more strongly related to exam preparation. As commented previously, these results are in agreement with the proposed objectives for each subject. Finally, for SDOSL, neither the correlations relating Q8 with Q4 and Q5 nor Q9 with Q4 and Q5 are significant.

As for the primary conclusions of this multivariate analysis, it can be stated that the acquisitions of both skills are highly related. Classes in cooperative classrooms clearly have a positive influence here. The students enjoy classes, and good relations with teachers are promoted. The correlation of the skills with outcome learning is subject dependent and agrees with the specific objectives proposed for each subject.

Although not a primary aim of this paper, the correlations of public speaking skills (Q10) have been also analyzed. There is a high correlation with teamwork skills, and the correlation with learning outcomes is clearly subject dependent.

3.3 *Satisfaction indicator*

In the survey there is no question in which students directly indicate their satisfaction with the neither methodology, nor are there questions concerning the specific features students consider more important.

However, all questions included in the third part of the survey are directly related to satisfaction. In previous section we have commented that Q11 and Q15 can be considered as global measures of satisfaction.

When principal component multivariate analysis is performed for questions Q11 to Q15, all belonging to third part, only one component is extracted with eigenvalue equal to 3.25 (sample size = 238). It accounts for 65% of variability in the original data. The equation of the principal component is:

$$Z = 0.47 \cdot Q11 + 0.43 \cdot Q12 + 0.45 \cdot Q13 + 0.40 \cdot Q14 + 0.48 \cdot Q15 \quad (1)$$

where the values of Q11 to Q15 are standardized by subtracting the means and dividing by their standard deviation. As can be seen, both Q11 and Q15 weights are quite similar.

In this section, the scores obtained through the principal component equation (Z) are used in order to construct a global satisfaction indicator (GS), and to quantify the effect of features (attributes).

The equation for satisfaction indicator is:

$$GS = W_1 X_1 + W_2 X_2 + \ldots + W_k X_k, \quad (2)$$

where W_i are the weights (importance), and X_i are the attributes to be considered.

Weights W_i are constants to be determined and must satisfy two conditions: $W_i >= 0$ and $sum(W_i) = 1$.

With these conditions, the *GS* scale is the same as the attributes scale X_i. For instance, if all the attributes have the maximum score 5, the *GS* value will be 5.

Weights are obtained from correlations between the *GS* values, which are calculated from the principal component equation and the attributes (questions Q1 through Q10 of the survey).

It can therefore be concluded that the higher the correlation (positive) with the global satisfaction, the higher the influence.

It must be mentioned that the results obtained are not substantially modified if questions Q11 and Q15 are considered as global indicators instead of having been obtained through principal components.

There are two main alternatives for obtaining attribute weights:

1. $W_i = r_i/sum(r_i)$
2. $W_i^* = r_i^2/sum(r_i^2)$,

where r_i is the correlation between global satisfaction and each one of the attributes. In our case, both give similar results. Fig. 9 shows the attributes ordered by their contribution to satisfaction.

It can be shown that the most important attributes in global satisfaction are Q1 and Q4, both belonging to outcomes learning; teamwork skills (Q9) and creativity (Q8) have similar weights, and Q7 and Q2 clearly have the lowest weights.

Similarly, global satisfaction indicators could be constructed for each specific subject.

3.4 Actual benefits

There are two types of benefits of the approach followed for promoting professional skills: benefits for students and benefits for professors.

The main benefit for students is the perception of more easily learning the technical concepts of their subjects and skills necessary for their professional careers.

Another benefit is that which is analyzed in Q6 ("It promotes student-professor communication"). With the use of this type of classroom, greater confidence and communication is established between student and professor, a fact perceived by both. In all subjects, the most participative methodology leads to the most creative solutions to the problems posed.

4. Future issues

Through the results of this study, which will be used in methodology renovation, we hope to encourage other university professors to use cooperative classrooms for the development of creativity and teamwork skills. The purpose of making known the results of this pilot experience, carried out across widely varying subjects at the Technical University of Madrid, is to help and encourage professors to offer classes following a non-traditional methodology that foments such skills as creativity and teamwork.

5. Conclusions

The results of this work are very satisfactory and coincide with UPM professor intuitions about the use of cooperative classrooms to foster creativity and teamwork skills.

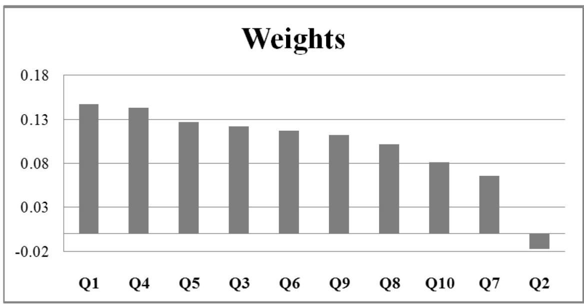
This study is valuable as the first of its type carried out at ETSII-UPM. It assimilates very different subjects, associated with different degrees, academic semesters, student backgrounds, and having different objectives and methodologies. This makes this paper a valuable overview of creativity and teamwork skills as seen by students and professors.

The results of surveys among the students (250 answered the survey) from six different subjects have been statistically analyzed using univariate and multivariate techniques. The paper mainly presents analysis results in three areas: learning outcomes, competency results (team working and creativity) and satisfaction.

Regarding learning outcomes, it can be seen that students consider the methodology of paramount importance in improving conceptual understanding and better exam preparation.

Results for competency clearly indicate that students give very high scores to of creativity and teamwork skills: 134 students out of 249 assign a score of 4 or 5 to creativity (54%) and 185 out of 249 assign a score of 4 or 5 to teamwork (74%). We conclude that the use of the collaborative classroom is essential in promoting teamwork skills, and also for creativity (with a slightly lower mean). These results are logical because teamwork skills appear in the syllabi of all analyzed subjects, while creativity only appears in some.

As to satisfaction, it is clear that students are



Question (attribute)	Counts	Weight
Q1	231	0.1472
Q4	227	0.1436
Q5	223	0.1266
Q3	225	0.122
Q6	230	0.1169
Q9	232	0.1126
Q8	232	0.1016
Q10	222	0.081
Q7	233	0.0659
Q2	223	-0.0175

Fig. 9. Attributes ordered by their contribution to satisfaction.

highly satisfied with the methodology and would repeat the experience.

Multivariate analysis identifies relations between different features. Results reveal that the acquisition of creativity and teamwork skills are closely related, enhance conceptual understanding, and aid exam preparation. Besides, while students acquire these skills they like the methodology and enjoy their time in class. Therefore, all the results go in the same direction and the teaching/learning methodology enthuses students. Obviously, these results suffer some minor change when a stratified analysis by subject is performed. Finally, a satisfaction indicator has been constructed and the most important attributes identified, ordered by weight: outcomes learning, as in "I learn much more during class time" (Q1) and "My conceptual understanding is better" (Q4), followed by teamwork skill (Q9) and creativity (Q8) with similar weights, and finally with the lowest weights "It promotes relationships with my companions" (Q7) and "I take advantage of my time better when I study at home" (Q2).

Therefore it can be concluded that classes in cooperative classrooms have a positive influence on creativity and teamwork skills. We infer a high correlation between both skills and students willingness to repeat with the methodology.

This paper provides promising results. More in-depth analyses may be conducted, either including other skills or measuring students' improvement as well as their perceptions.

Acknowledgements—We want to thanks to Prof. Fernando Matía, Prof. Nuria García and Prof. Oscar L. Cabellos for their collaboration on this work.

References

1. C. R. Rogers, *On Becoming a Person: A Therapist's View of Psychotherapy,* Houghton Mifflin Company, New York, 1961, pp 348.
2. Pappas, E. Creative Problem Solving in Engineering Design, *Proceedings of the American Society of Engineering Education* (*ASEE*) South-eastern Section Conference, 2002, **12**, pp. 135–147.
3. P. L. Hirsch and A. F. McKenna, Using Reflection to Promote Teamwork Understanding in Engineering Design Education, *International Journal of Engineering Education* **24**, (2), 2008, pp. 377–385.
4. J. P. Guilford, *The Nature of Human Intelligence*, McGraw-Hill, New York, 1967, pp 538.
5. The CDIO Initiative, http://www.cdio.org/files/crawleyetalcdiosyllabus2.0paper_29may2013.pdf, Accessed 16 July 2013.
6. R. M. Felder, Creativity in Engineering Education,*Chemical Engineering Education*, **22**(3), 1988, 120.
7. A. Johri C. Williams and J. Pembridge, Creative Collaboration: A Case Study of the Role of Computers in Supporting Representational and Relational Interaction in Student Engineering Design Teams, *International Journal of Engineering Education*, **29**(1), 2013, pp. 33–44.
8. T. Bjørner L. B. Kofoed and J. R. Bruun-Pedersen, Creativity in Project Work: Students' Perceptions and Barriers, *International Journal of Engineering Education*, **28**(3), pp. 545–553.
9. C.-F. Zhou et al., Factors Influencing Group Creativity in Project-organized Teams in Engineering Education in China, *International Journal of Engineering Education*, **26**(6), 2010, pp. 1524–1535.
10. A. Parkinson et al., Global Virtual Teams: A New Frontier for Capstone Design, *International Journal of Engineering Education*, **27**(6), pp. 1221–1230, 2010.
11. P. D. Ball, H. J. Grierson, J. Min, K. Jackman and P. Pattterson, Working on an Assignment with People you'll Never Meet! Case Study on Learning Operations Management in International Teams, *International Journal of Engineering Education*, **23**(2), 2007, pp. 368–377.
12. K. Lau, S. L. Beckman and A. M. Agogino, Diversity in Design Teams: An Investigation of Learning Styles and their Impact on Team Performance and Innovation, *International Journal of Engineering Education*, **28**(2), 2012, pp. 293–301.
13. E. Froment, The European Higher Education Area: A new framework for the development of Higher education, *Higher education in Europe*, XXVIII (1), pp. 27–31, April 2003.
14. Bologna Process-European Higher Education Area, http://www.ehea.info/article-details.aspx?ArticleId=5, Accessed 25 July 2013.
15. Accreditation Board for Engineering and Technology, Engineering Criteria 200, ABET, Inc., Baltimore, (MD) (2000), http://www.abet.org (accessed 25 July 2013).
16. N. Fang, Improving Engineering Students' Technical and Professional Skills Through Project-Based Active and Collaborative Learning, *International Journal of Engineering Education*, **28**(1), 2012, pp. 26–36.
17. SAUL, Jeffery M., et al. *Introduction to SCALE-UP: Student-centered activities for large enrollment university physics*. US Department of Education, Office of Educational Research and Improvement, Educational Resources Information Center, 2000.

Raquel Martínez holds a Ph.D. in Mathematical Sciences from the Universidad Politécnica de Madrid (U.P.M.). Since 1980, she is Associate University Professor on the Department of Control Electronics and Industrial Computing at U.P.M. She is a member of the research group Computer Sciences Applied to Education and Knowledge Representation, and she is also responsible for the innovation education group Learning Representation and Evaluation. She is co-director of the web-based learning platform AulaWeb, one of the most widely used platforms at UPM. She has been the main researcher on national and international projects in the areas of Computer Algebra and e-learning. She has also published articles in international journals and presented papers at conferences in the areas of computational algebra, e-learning, and software development applied to education.

Camino González received her degree in 1987 and her Ph. D. in Nuclear Safety in 1993, both from the Universidad Politécnica de Madrid. Since 1993 she has been Associate Professor at the Statistics Laboratory at U.P.M. She is member of the Computational Statistics and Stochastic Modeling research group, in which she is responsible for statistical design and quality control areas. She is also a member of the educative innovation group Stochastic Modeling in Teaching, also at the U.P.M. Since 1994 she has been a member of the American Society for Quality. Her current fields of interest include applied statistics, simulation, data mining and teaching learning methodologies.

Pascual Campoy is Chair Professor of Automatics at the Universidad Politécnica Madrid (UPM), where he received his Ph.D. in Engineering in 1988. He presently lectures on control, machine learning and computer vision at graduate and post-graduate levels. He has been in charge of a wide variety of research projects concerning technology transfer of computer vision to the industry. He has been leader of twelve Projects funded by the European Commission, seven national R&D projects and over projects contracted directly by the industry. He holds nine patents in the field of computer vision, three of them registered internationally. His research activities have been gathered in more than 100 international publications in technical journals and symposia contributions, with 652 cites and a H number of 13. He is presently leading the research group on computer vision at U.P.M. His has a large activity in using vision for unmanned aerial vehicles (UAV), which includes object tracking, visual serving, visual control and guidance, visual SLAM, stereo and omni-directional vision. He is presently working on new learning paradigms for bio-inspired neural networks that are aimed for use in image segmentation and detection recognition.

He strongly believes in active and collaborative learning, being a pioneer in using the SCALE-UP methodology in ETSII-UPM since 2007, when collaborative classrooms were implemented. He is the founder of the ISA student association at UPM and its Advising Professor in the period 2004–2012.

Álvaro García-Sánchez is a professor at the ETSI Industriales, Universidad Politécnica de Madrid (UPM) in Spain. He obtained his degree in Industrial Engineering and his Ph.D. from the same university. His main areas of interest are simulation and optimization for production and logistics. He lectures in graduate, postgraduate and Ph.D. courses at the UPM and used to coordinate the Master's and Ph.D. program in industrial engineering ('Ingeniería de Organización'). He also collaborates with other universities and offers training for companies. In addition, he has close contact with the professional world, carrying on consulting activities, which led him to set up a company in 2011, making the best of the synergies derived his consulting and academic activities.

Miguel Ortega-Mier is associate professor in the Industrial Engineering School at the Universidad Politécnica de Madrid. He teaches courses on operations research and operations management. He belongs to a group of professors who work for innovation in higher education.