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Cooperative Dynamic Approach in Engineering Teaching: Same Content and Trend Towards Better Result

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Abstract

This article shows the benefits of active learning compared to traditional learning. It proves the importance of a fruitful discussion between peers. It is a sample of methodological change with no curricular change. It also shows the overall satisfaction of the students, who achieved an equal or better academic performance than the students in the traditional learning environment. At the Faculty of Engineering in Bilbao, Engineering Graphics is a collegiate subject and it is assessed using a final exam. In the 2015/2016 and 2016/2017 academic years, didactic interventions were carried out, introducing active methodologies in the experimental group, keeping the same content and evaluation as the control group. It is important to mention that the subject of Engineering Graphics is taught in large groups and with novel students of first course of engineering. A cooperative dynamic (jigsaw) was selected. The main feature of this method is that the students' knowledge is developed by themselves and the teacher does not explain any theory and practice linked to the subject. The teacher advises students in their learning process. The quantitative and qualitative analysis of the data collected shows that the use of a cooperative dynamic has a positive effect on the learning process of the students.

Introduction

This didactic intervention and its subsequent analysis, both of them described in this article, were carried out in search for improvements in the teaching of technical subjects. First, the context of this didactic intervention is established and then, the methodology is described in detail. Subsequently, the data resulting from this didactic intervention is used to justify the conclusions presented in the last section.

The active methodologies are a guarantee of improvement in education and the cooperative dynamics are a very valuable tool in this sense (Wilson and Harris, 2003). Cooperative dynamics increase student engagement with learning (Zepke and Leach, 2010).

Although at a theoretical level these active methodologies are well known, their application is a source of uncertainty and mistrust for some teachers with a lack of experience with these methodologies. Furthermore, some teachers have raised a campaign against these active methodologies without having experienced them: they argue that these active methodologies lead to worse academic results and involve a reduction of content, together with a need for more material, human and time resource (Nguyen et al, 2017) (Sherman, Sanders and Kwon, 2010).

This article presents a real cooperative dynamic experience and compares the results obtained with this dynamic with the results obtained following the traditional methodology. In both cases, the content to be learned by the students and the evaluation method were the same.

This didactic intervention took place in a course where there is an inertia towards traditional teaching, a lecture centered class with a selection of exercises solved by the teacher and then, in-

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dividual work of the students with an evaluation system consisting in a final exam.

The inertia corresponding to the traditional system is based on the transmission of knowledge (concepts, processes and attitudes). The teacher first presents the theoretical basis of the content and then presents a selection of exercises, often accompanied by the result (Sierra eta al, 2013). In this way, the curriculum becomes a sequence of theory and procedures according only to the expository speed of the teacher, the learning does not happen thanks to a student developed activity program, one through which to assimilate these concepts, procedures and attitudes.

As a result, most students will only know how to solve the type of exercises explained by the teacher. The students depend entirely on the teacher´s explanations to move forward on their learning process and this constitutes a passive dependency because the student only listens and only participates actively when asked to solve an exercise similar to those explained previously in class by the teacher. In summary, the student only knows how to walk along the path previously followed by the teacher (Garmendia, Gisasola and Sierra, 2007) (Gisasola et al, 2002).

In this study, cooperative dynamics (Pujolas and Lago, 2013) (Johnson DW, Johnson RT and Stanne, 2000) are used to promote the student´s autonomy and activity (Vygotsky, 1934).

The didactic intervention described in this article does not modify the competences, content and evaluation system of this course. The cooperative dynamic, called jigsaw or puzzle is characterized by the sharing of knowledge among the students of the group with the aim of helping each other analyze and share their knowledge, all of this without a previous explanation from the teacher.

In this way, cooperative dynamics promote the students' autonomy and implication in their own learning. This method requires a minimum adaptation, a minimal time and economic investment. Therefore, these types of cooperative dynamics constitute a very profitable way to promote active learning without a major resource investment.

Methodology

At the Faculty of Engineering in Bilbao, in the first year of these studies, there are five groups of freshmen, and two groups of students who are repeating the course. The criteria followed to create these groups are the access mark of the students and the language of instruction (Basque, Spanish or English).

In the 2015/2016 academic session, 3 of the 5 first call groups participated in this research: two of them constitute the control group and the third one is the experimental group. In the 2016/2017 academic session, the control group consisted of four of the five first call groups, whereas the remaining group was the experimental group.

In the beginning, a survey collects data about the student education prior to their University experience (created specifically for this study) and a standard Visualization Test is given to all novice students. The resulting data prove the homogeneity between the control and the experimental groups. At the end of the quarter, another specifically created survey is carried out with the students in the experimental group. The resulting data will be used for a qualitative analysis to prove the validity/students' appreciation of this cooperative dynamic.

When following this dynamic cooperative (Pujolas and Lago, 2013), 1/3 of the Graphic Expression subject is developed throughout three weeks (teaching guide, 2016). This part of the content of the course corresponds to one of the final exam exercises. This exercise serves as a quantitative contrast between the experimental and the control groups.

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In addition to this quantitative data, qualitative data was used in this study. A posterior test with closed (Likert 1-5) and open-ended questions was conducted, proved appropriate tools to perform the analysis of the intervention carried out (Sahdish, Cook and Campbell, 2002).

Throughout three weeks, the students in the experimental group work in cooperative groups of four students. This jigsaw dynamic consists of three phases.

In the first phase, each student develops individually the part of the content assigned to him/her. Each of the students follows the specific bibliography and exercises assigned to his/her part. In fact, this part is carried out following the flipped classroom strategy (Lucke, Dunn and Christie; 2017). At the end of this phase, all students with the same assignment meet and help each other solve their doubts. At the end of this phase all students are responsible for understanding in great detail the content knowledge and mastering their part (the help of the peer directed collaborative work and the initial and subsequent guidance and advice of the teacher ensure that all students can achieve the objective desired).

In other words, the student faces the discovery of the new knowledge individually first, and later on, following the inverted class strategy, he can count on the help of his/her colleagues. This group phase is the most efficient of the different types of inverted class (Foldnes, 2016).

In the second phase of the jigsaw dynamic cooperative, students come together in groups of four, each of them with a previous previously selected different assignment, and solve problems in which the four parts of the content are integrated. In this phase, the students can count on the assessment of the teacher on demand.

In the past phase of this didactic innovation, the learning process of the students is completed with the solving of more problems both in groups and individually without the assessment of the teacher.

This last part of individual and group exams is of vital importance in cooperative learning, since they give meaning and crystallize the achievements of student discussions (Herrmann, 2013).

Weeks later, in the final exam they will have to individually solve a specific exercise in this area of knowledge. The marks obtained in this specific problem of the final exam will serve as a quantitative contrast between the control and the experimental groups.

In summary, the groups following the traditional teaching method, which constitute the control group, kept on developing their knowledge following a sequential agenda with the teacher intercalating the resolution of exercises.

On the other hand, the experimental group developed the four aspects of the agenda "in parallel". In the first phase, each student learns only one aspect of the content, but in the rest of the phases, all the students work with the four aspects. The program of activities presented to them helps them to assimilate the contents while discussing the solutions to the different problems presented to them.

The teacher continues to play a vital role in the learning of the students, but in the face-to-face hours, he/she is not the center of the action. Instead, the teacher plays a fundamental role: he/she becomes the adviser or counselor and students seek his/her help only when they are stuck in a problem. It is the students themselves, in collaborative groups, who develop knowledge (Barak and Shachar, 2008) (Williams, 2011).

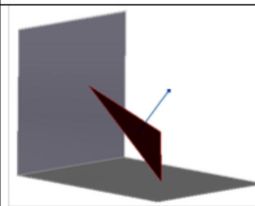
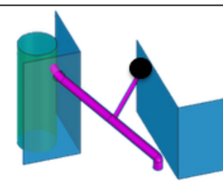
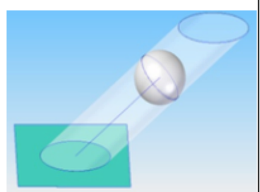
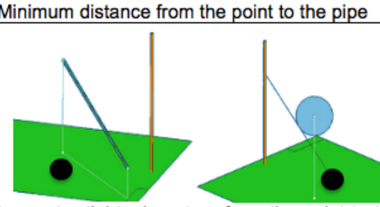
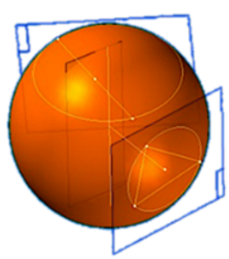
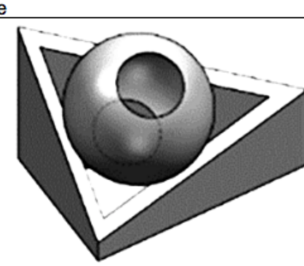
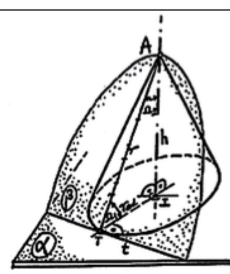
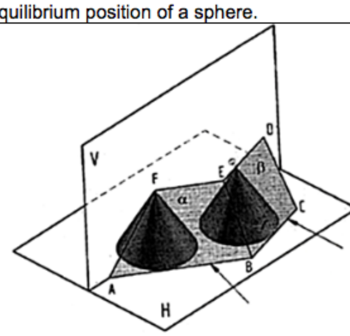
Geometric Locus

The above-mentioned didactic innovation was carried out using the content course known as Geometric locus. A set of points in space (or on a plane) that meet a certain common geometric condition constitute a geometric locus. Therefore, any geometric figure can be defined as the locus of points that meet certain properties, if all the points of this figure fulfill those properties and every point that fulfills them belongs to this figure (Bertoline and Wiebe, 2002). The purpose of this part of the content is to analyze the problem graphically and solve metrical and spatial position questions using the properties of the most common geometric locus in the technique (line, plane, cylinder, cone and sphere).

The content knowledge is divided into 4 sections (areas), each student in the group is assigned one, containing a required and additional suggested bibliography, composed of different book chapters and internet based educational free resources. This bibliography describes the properties and applications of the assigned section or

Table 1

Geometric locus content division and exercise samples.

Assigned content or surface	Graphic knowledge sample	Sample exercise
Plane and normal (perpendiculars, and minimum distances)		 Minimum distance from the point to the pipe
Cylinder (constant distance to axis)		 Lay out a tightening strap from the point to the post that covers the minimum distance to the cable
Sphere (constant distance to a point)		 Equilibrium position of a sphere.
Cone (constant angle to plane or axis)		 You have to define the plane α and β (form 60º with the horizontal plane) the angular conditioning of the planes is solved by cones

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surface. To apply the content knowledge, the students receive also, a large pool of targeted exam exercises to work with.

The following is an examination exercise Figure 1.

SHAFT SUPPORT: The PQ axis is located, knowing its length (75mm), the position of the point Q (50, 40), the height of the point P (40) and the angular condition of 45° with respect to the plane β. Plane β is 60° to the horizontal plane α.

Figure 2. shows the cone that fulfills the angular condition. Its generatrix lines form 45° with the plane β, its axis is perpendicular to the plane β. The straight solution will be the intersection of the cone with the horizontal plane of height 40 (PQ).

Data Collection and Analysis

In order to proof the comparability of the experimental and the control groups, the above mentioned survey (created specifically for this study) and Visualization Test (Titus and Horsman, 2005) (see Figure 4.) were carried out by all the students.

These activities were voluntary and they were carried out via the university's Moodle platform, this is, via eGela, the virtual classroom developed by the EHU/UPV as a support for its teaching.

The Data Protection Regulation of the EHU/UPV, together with the general Data Protection Law of Spain in force have been strictly followed. A high security file was opened for the Basque Data Protection Agency under the name INA-0062 with a registration No. 2080310018.

The Statistical analysis of the data was performed with the IBM SPSS statistics 24 program.

In the 2015/2016 academic session, 3 of the 5 first call groups participated in this research: two of them constitute the control group (150 students) and the third one is the experimental group (76 students). In the 2016/2017 academic session, the control group consisted of four of the five first call groups (280 students), whereas the remaining group has been the experimental group.

In order to expand the sample size for statistical analysis, the Total Control Group (TCG) is also re-

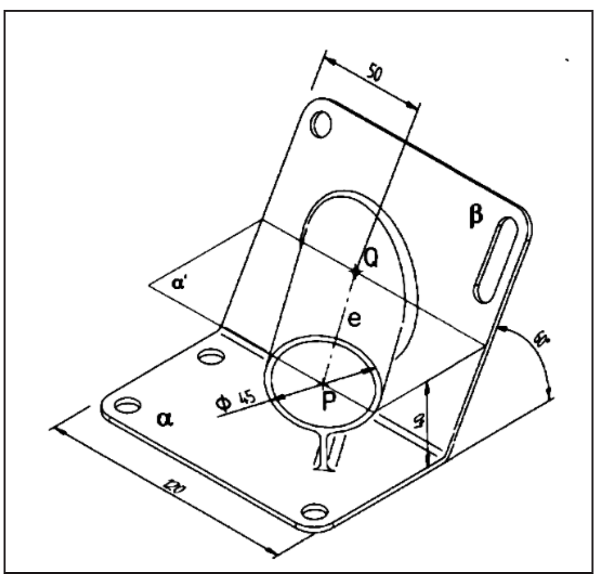

Figure 1. Final examination exercise.

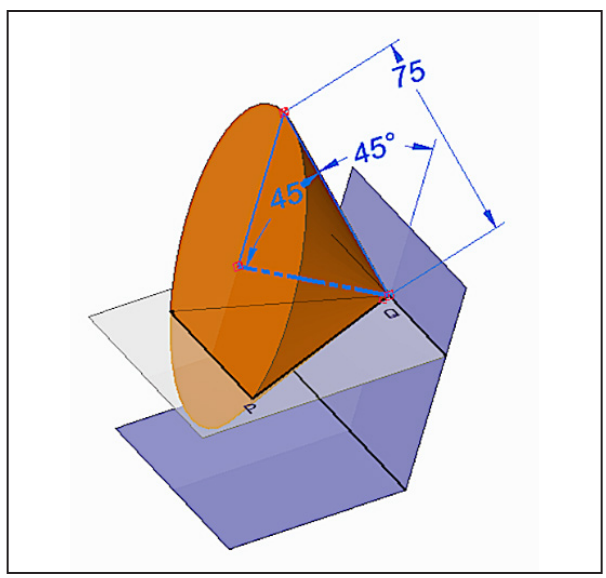

Figure 2. Way of resolution.

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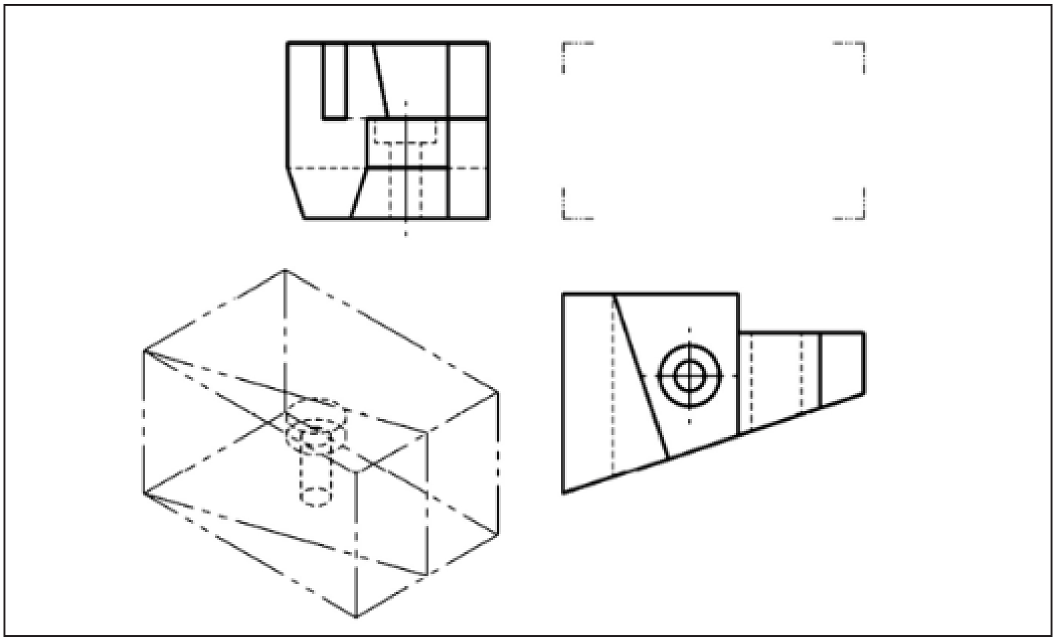

Figure 3. Example of Exercise of the graphic expression exam of the university admission examination (complete views and perspective).

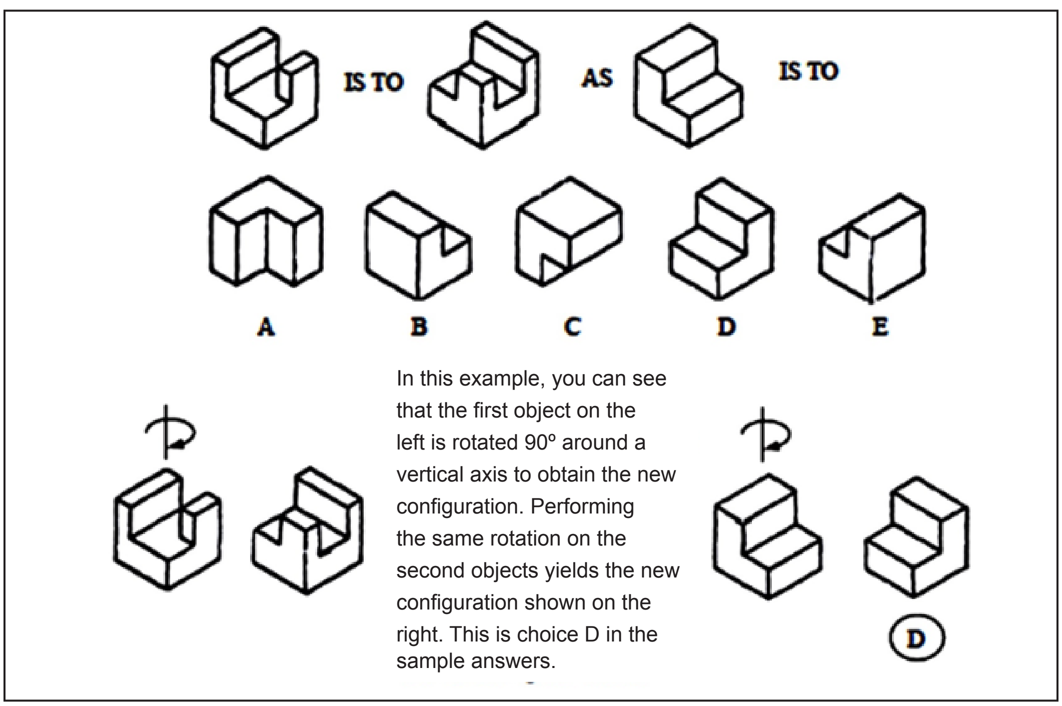

Figure 4. Sample of the Visualization Test, first part of three.

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flected in the analysis as the sum of all the control groups.

Table 2 shows in column the access mark required to enter the School of Engineering of Bilbao. This mark is a weighted average between the average mark of the two academic years previous to the start of Higher Education and the mark obtained in the university admission examination. The maximum possible score in this column is 14.

The second column shows the mark obtained at this admission examination, which consists of different exams regarding different areas of knowledge. This is a standard instrument

The third column shows the mark obtained in the graphic expression exam of this admission examination. This is a standard instrument. See a sample in Figure 3.

The average mark (AM) and the standard deviation (SD) are shown for each group.

Table 2 also shows the results of the Visualization Test, with a maximum possible score of 45 points. This test assesses at the beginning of the course the spatial capacity of the students, a skill that is closely related to graphic expression. This is a standard instrument. See a sample in Figure 3.

Table 2 also shows the number of students enrolled (M), as well as the number (N) and percentage (%) of students who have responded to the survey and performed the Visualization Test.

The first analysis of these data reflects a greater level of reflection on their learning circumstances in the experimental group. The percentage of students responding to the survey is clearly higher in the experimental group (>90%), and this accounts for their greater engagement in their own learning.

In the 2015/2016 academic year, the experimental group versus the total control group is the highest in access mark and examination mark, but there is a control group with a better mean than the experimental group.

In the 2016/2017 academic year, the experimental group versus the total control group was the

Table 2

Data of the groups at the beginning of the course.

2015		ACCESS MARK			EXAMINATION MARK			GRAPHIC EXPR. MARK			VISUALIZATION T. MARK		
2016	M	AM	SD	%	AM	SD	%	AM	SD	%	AM	SD	%
Exp.G	**76**	**11.32**	**1.11**	**94.74**	**8.02**	**0.80**	**93.42**	**6.97**	**1.77**	**64.47**	**21.9**	**8.05**	**92.11**
TCG	**153**	**11.12**	**1.35**	**33.33**	**7.88**	**0.94**	**31.37**	**7.58**	**2.03**	**24.84**	**19.3**	**7.45**	**47.06**
CG1	74	10.78	0.96	31.08	7.67	0.78	28.38	7.37	1.98	20.27	16.4	7.69	55.41
CG2	79	11.41	1.56	35.44	8.09	1.02	34.18	7.78	2.08	29.11	19.7	6.81	39.24

2016		ACCESS MARK			EXAMINATION MARK			GRAPHIC EXPR. MARK			VISUALIZATION T. MARK		
2017	M	AM	SD	%	AM	SD	%	AM	SD	%	AM	SD	%
Exp.G	**72**	**11.30**	**0.86**	**94.44**	**7.98**	**0.65**	**94.44**	**6.55**	**1.94**	**63.89**	**20.43**	**7.30**	**87.50**
TCG	**283**	**10.80**	**1.32**	**76.33**	**7.67**	**0.98**	**74.20**	**6.58**	**2.37**	**49.82**	**18.89**	**7.60**	**67.14**
CG1	79	10.3	1.61	65.82	7.5	0.90	64.56	5.8	2.51	43.04	19.1	6.54	55.70
CG2	74	11.1	0.85	95.95	7.7	0.90	94.59	7.0	2.05	68.92	19.5	8.12	83.78
CG3	70	9.5	1.38	52.86	7.4	0.92	50.00	6.8	2.00	27.14	16.8	10.15	57.14
CG4	60	11.0	1.31	93.33	7.9	0.98	90.00	6.4	2.77	61.67	19.4	7.03	73.33

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one with the best mean but with a control group very close to it.

In 2015/2016 and in the 2016/2017 academic years the experimental group lowest average corresponds to graphic expression mark, obtained the worst mean but quite similar of the control groups mean.

In the visualization test, the experimental group obtained the best results. In the 2015/2016 academic year, the difference was significant, but there was a certain uncertainty, since very few students in the control group (47%) did the same test.

The data reflects a certain equality of means in all the sections (table1), few cases of comparison have statistically significant differences. The statistical differences are shown with a YES/NO in Table 3.

The values reflected in the Table 2. and 3. proof the homogeneity of the experimental and control groups. In both academic years, the values are similar for all groups and the experimental group is not always the best.

Table 4. shows the marks in the exercise regarding locus in the final exams for the experimental group (Exp.G), for the Total Control Group (TCG) and the individuals Control Groups (CG1, CG2, CG3 and CG4): Number enrolled (M); Number submitted to the exam (N); Approved number (A); 1%: percentage of students over enrolled; 2%: percentage of students over submitted; average mark; Standard deviation; median; percentile and average standard error.

The data of the final exam exercise (Table 4. and 5.; Figure 5. and 6.) shows a pattern: the experimental group shows a trend to be above the control group.

The data expressed in both Table 4. and Figures 6. and 7., which represent box diagrams, reflect that the academic results, that is, the results of the evaluation examination, are more satisfactory in the experimental group than in the control group. In most of the values reflected, the experimental group is always above (values for the experimental and Total Control group):

- Greater attendance to the final evaluation test (94% and 87% vs 81% and 79%)
- Highest number of passing grades (9% and 12% versus 4% and 2%)
- Better average score (2.62 and 2.59 versus 1.79 and 1.90)
- Better median (2.5 and 2 vs 1.75 and 1.19)
- Better percentiles (1.5 / 2.5 / 3 and 1/2/4 vs. 0.5 / 1.75 / 2.38 and 0.75 / 1.19 / 3.41).

Table 3

Statistical differences at the beginning of the course (median test for independent samples) (Bilateral sig. in parenthesis).

2015/2016	Exp.G & TCG	Exp.G & CG1	Exp.G & CG2
ACCESS MARK	NO (0.940)	-	-
EXAMINATION MARK	NO (0.628)	-	-
GRAPHIC EXPR. MARK	NO (0.120)	-	-
VISUALIZATION T. MARK	**YES (<0.0001)**	**YES (<0.0001)**	**YES (0.004)**

2016/2017	Exp.G & TCG	Exp.G & CG1	Exp.G & CG2	Exp.G & CG3	Exp.G & CG4
ACCESS MARK	**YES (0.003)**	NO (0.355)	NO (1.00)	**YES (0.003)**	NO (1.000)
EXAMINATION MARK	**YES (0.036)**	NO (0.069)	NO (0.171)	NO (1.000)	NO (1.000)
GRAPHIC EXPR. MARK	NO (0.492)	-	-	-	-
VISUALIZATION T. MARK	NO (0.054)	-	-	-	-

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Table 4

Data of the final exam exercise.

2015/16	Enrolled M	Submit-ted N	% N/M	Approved A	%1 A/M	%2 A/N	Average Mark	Standard Deviation	Median	Percentile 25	Percentile 50	Percentile 75	Av.St Error
Exp.G	**76**	**72**	**94.7**	**7**	**9.2**	**9.7**	**2.62**	**1.94**	**2.5**	**1.5**	**2.5**	**3**	**0.22**
TCG	**153**	**125**	**81.7**	**6**	**3.9**	**4.8**	**1.86**	**1.77**	**1.75**	**0.5**	**1.75**	**2.3**	**0.15**
CG1	74	56	75.6	1	1.3	1.7	1.13	1.24	1	0	1	1.75	0.16
CG2	79	69	87.3	5	6.3	7.2	2.45	1.92	2.5	1	2.5	3.0	0.23

2016/17	Enrolled M	Submit-ted N	% N/M	Approved A	%1 A/M	%2 A/N	Average Mark	Standard Deviation	Median	Percentile 25	Percentile 50	Percentile 75	Av.St Error
Exp.G	**72**	**63**	**87.5**	**8**	**11.1**	**12.7**	**2.59**	**1.76**	**2**	**1**	**2**	**4**	**0.22**
TCG	**283**	**226**	**79.8**	**5**	**1.7**	**2.2**	**1.97**	**1.62**	**1.19**	**0.75**	**1.19**	**3.41**	**0.20**
CG1	79	57	72.1	2	2.5	3.5	1.87	1.54	1	0.5	1	3.5	0.20
CG2	74	60	81.1	1	1.3	1.6	2.25	1.85	1.5	1	1.5	4	0.21
CG3	70	55	78.5	0	0.0	0.0	1.36	1.38	0.5	0.5	0.5	2.65	0.19
CG4	60	54	90.0	2	3.3	3.7	2.12	1.52	1.75	1	1.75	3.5	0.18

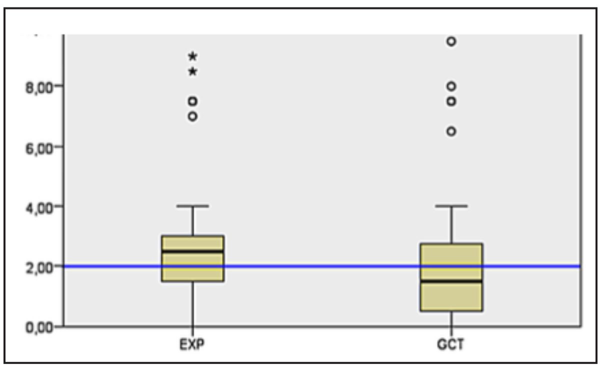

Figure 5. Diagram boxes of exam mark 2015/2016.

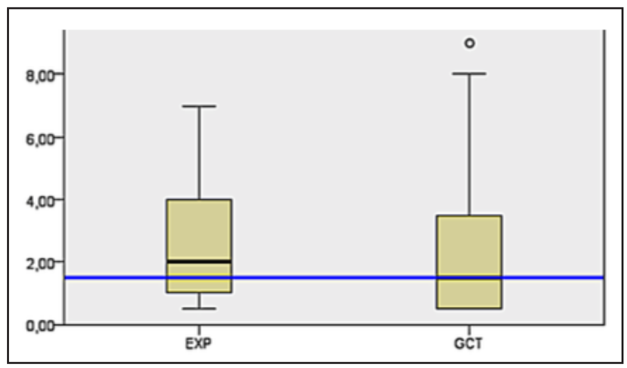

Figure 6. Diagram of boxes of exam mark 2016/2017.

Table 5. shows the comparisons between groups and it cannot be said that the experimental group is significantly better. There are statistically significant differences in the 2015/2016 academic session against TCG and CG2, but not in the 2016/2017 academic session.

Although more statistical data is presented, no further conclusion was obtained with the analysis of this data. This analysis intends to objectively present a clear conclusion that shows a trend pointing to better results in the final evaluation from the experimental group than from the control group.

Table 5

Statistical Differences for the Exam Exercise mark (median test for independent samples) (Bilateral sig. in parenthesis).

2015/2016	Exp.G & TCG	Exp.G & CG1	Exp.G & CG2
EXAM MARK	**YES (0.013**	NO (0.469)	**YES (>0.001)**

2016/2017	Exp.G & TCG	Exp.G & CG1	Exp.G & CG2	Exp.G & CG3	Exp.G & CG4
EXAM MARK	NO (0.073)	-	-	-	-

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Table 6

Data from the satisfaction of Experimental Group survey 2015/2016 (Likert scale 1-5) average (standard deviation).

Traditional Methodology		Cooperative Methodology (Jigsaw)	
Do you understand the teacher?	3.54 (0.901)	Do you understand your partner?	3.94 (0.630)
Traditional Motivation	3.36 (0.828)	Motivation jigsaw	3.89 (0.602)
Effort in class	3.43 (0.957)	Effort in class	3.85 (0.812)
Effort at home	3.86 (0.943)	Effort at home	3.52 (0.841)

Table 7

Data from the satisfaction of Experimental Group survey 2016/2017 (Likert scale 1-5) average (standard deviation).

Traditional Methodology		Cooperative Methodology (Jigsaw)	
Do you understand the teacher?	3.51 (0.658)	Do you understand your partner?	3.74 (0,638)
Traditional Motivation	3.18 (0.772)	Motivation jigsaw	3.71 (0,714)
Effort in class	3.04 (0.969)	Effort in class	3.81 (0,815)
Effort at home	3.99 (0.782)	Effort at home	3.52 (0.841)

The students of the experimental group were asked to assess the two different types of teaching on a Likert 1-5 scale, and they had the opportunity to express their opinion (open-ended question). The Table 6. and 7. below shows these results and opinions. This survey has been specifically done for this study.

The experimental group claims to understand their partner better than the teacher (see Table 7. and 8.). On the other hand, even though cooperative classes are more demanding for the students during face-to face hours, they find these classes more motivating. This greater effort during the classes is compensated by a lesser effort during non-face-to-face hours.

Table 8

Data from the satisfaction of Experimental Group survey 2015/2016 and 2016/2017 (open question).

Open Question: **"How do you learn best in expository class or cooperative class?"**		
2015/2016	8 in favor of traditional (10%)	55 in favor of cooperative (74%)
2016/2017	5 in favor of traditional (7%)	56 in favor of cooperative (82%)

Traditional Highlights	**Cooperative Highlights**
“The concepts become clearer to me”	“I solve the doubts at the moment and classes are more dynamic”
“I do not manage well in the groups, I prefer to do it alone”	“those who do not dare to ask the teacher we resolve the doubts between us”
“Because the teacher explains”	“we are forced to work for the classmates”
“The explanations of the teacher are necessary before doing anything”	“we have more time to receive explanations and it is more personal”
“Everyone must correct their own mistakes”	“you have 3 sources of knowledge: you, the classmates and the teacher”
“Lack of security in the knowledge of colleagues”	“we strive more, I improve more, I entertain more”
“we ran out of ideas”	“we understand each other better”
“If nobody knows the answer we get stuck”	“having to explain to classmates internalized better”

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This survey also shows (see Table 8.) that the belief that the teacher is the only expert (Kelly and Fetherston, 2008) is a minority belief. It counteracts with some arguments in favor of motivation and shared knowledge.

Conclusion

The casuistry of the learning-teaching process is very complex and it is not the purpose of this article to delve into all causes or to comprehensively measure their effects. But rather to show a tendency to improvement in teaching, by showing a real experience of active and group learning through a cooperative dynamic in which both agents of the learning process, teacher and students, find highly satisfying.

The marks of the exercise that serves as evaluation tool show a tendency to a better result in the experimental group. In addition, it should be pointed out that the rate of attendance to the academic sessions was higher in the experimental group. The greater attendance by the experimental group reflects the greater "engagement" felt by the student. Therefore, in this experience, the teaching carried out in cooperative groups is as effective or even more than the traditional teaching.

The conclusion of the survey of satisfaction and opinion is that the students ask for more teaching of this type. This petition reflects a need to make learning more democratic and make students participate more in their own learning (Snape and Turnbull, 2013) (Bencze, 2010, 2000).

Being conscious that the teacher has an influence on the attitude of the students about their active learning (Nguyen et al, 2017), it is necessary to point out that the main activity of the teacher has been to remain silent, to observe and to advise. In the cooperative dynamic used in this case, most of the time students interact face-to-face with each other in groups, without the influence of the teacher. It can be assumed then that the influence of the teacher is minimized. The teacher's job is to design the learning situation and advise students throughout its development. These deep learning situations are the ones that hook students on their own learning (Kuh et al., 2006). A reflection of this opinion is found in the response of a student in the satisfaction survey: "the best of the course".

In the beginning, students are reluctant to make the required effort, but later on, their results prove to be better.

The quantitative and qualitative analysis of the data collected, shows that the use of cooperative dynamics is beneficial for teaching, taking into account also that the subject of Engineering Graphics is taught in large groups and with new students of 1st course of engineering.

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