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The Learning Improvement of Engineering Students using Peer-Created Complementary Resources

María Luisa Sein-Echaluce
Department of Applied Mathematics, University of Zaragoza, Campus Rio Ebro, University of Zaragoza. Calle de María de Luna 3, 50018 Zaragoza, Spain. E-mail: mlsein@unizar.es

Angel Fidalgo-Blanco
Laboratory of Innovation in Information Technologies. LITI. Technical University of Madrid. Calle de Ríos Rosas 21, 28003 Madrid, Spain. E-mail: angel.fidalgo@upm.es

Javier Esteban-Escaño
Department of Electronic Engineering and Communications, University of Zaragoza EUPLA, University of Zaragoza. Calle Mayor s/n, 50100 La Almunia de Doña Godina, Spain. E-mail: javeste@unizar.es

Francisco J. García-Peñalvo
GRIAL Research Group, University of Salamanca. Salamanca 37008, Spain. fgarcia@usal.es

Abstract

In any organization, the individual is considered an issuer of knowledge who can improve corporate knowledge, and learning is considered to be a key factor in promoting the creation of knowledge. As the knowledge of the individual increases, the organization's knowledge also increases. The same happens in educational institutions, but there is a tendency in most educational methodologies to consider the student as a mere recipient of knowledge. This paper presents a model where the student is shown as a knowledge issuer both for their own benefit and for their peers. The key idea is the transfer of knowledge produced by students to organizational knowledge through the knowledge management system the Collaborative Academic Resources Finder (BRACO, for its acronym in Spanish). At the same time, certain quantitative measurement instruments provide insight into student perception of the use of this knowledge in a particular subject in their engineering degree studies as well as the measure of BRACO impact on their learning outcomes. The results of this work show that an experimental group obtained higher scores in tests than a control group. Results also show that BRACO had a significant impact on learning, and students promoted, organized and used the resources generated by fellow students.

Keywords: knowledge spirals; knowledge sharing; cooperative learning; learning content management system; repository; teamwork competence; higher education

1. INTRODUCTION

Knowledge management has become a way to gain a competitive advantage in industries [1-2]. More specifically, the competitive advantage is related to the ability to conceptualize, transfer and use collected knowledge [3]. Nonaka and Takeuchi argue that an organization is a substrate for the creation of knowledge and must be strengthened by (and connected to) both internal knowledge generated by the organization itself and external knowledge [4]. For these authors, organizations learn and improve through the creation and conversion of knowledge by different groups within the organization. The role of the individual is essential to the success of an organization [5] because it contributes to the development of the organization and to the individual's own development [6].

Moreover, in an organization, the individual is considered a transmitter of knowledge who improves corporate knowledge, and learning is considered as a key factor to promote the creation of knowledge. This model is based on the fact that while knowledge of the individual increases the organization's knowledge also increases.

These principles can be applied in any educational organization and more particularly in the subjects of any degree. Individuals are students, the organization is the subject and knowledge is selected by teachers and used as teaching resources for the subject. However, the application of this model in academic training faces various difficulties. The main one is that the students are considered recipients of knowledge but not producers regardless of the learning paradigm employed.

It is unusual to consider students as producers of knowledge and, in turn, use that knowledge as a teaching resource to promote the learning of others, particularly those who do not coincide in space (the subject) or time (other academic courses). It is also unusual to consider that knowledge produced by the students can be used to improve knowledge of the subject itself.

During the development of a subject, students acquire knowledge as a result of the teaching resources used, the teaching method employed by the faculty and their own activity and capacity. The student is therefore able to produce useful knowledge of the subject [7]. But such knowledge is also useful to improve the course itself and even encourage the learning of students in another subject [8].

Transferring the knowledge management principles used in engineering to other engineering subjects is one of the research foci of the authors of this paper. Earlier work has shown that the student is able to generate knowledge related to the subject's content, using experience obtained studying the subject as well as knowledge of the degree and the college [7, 9]. Moreover, it has been shown that the faculty can use a selection of resources produced by students to improve their own course through improving learning, the regularity of work performance and interaction among students [8]. These studies were performed on teamwork competence, showing that teams are more active (exchanging more messages between members of the team), more regular (performing activities regularly without leaving it to the last day) and get better evaluations. Based on these previous results [8], the Collaborative Academic Resources Finder (BRACO, Buscador de Recursos Académicos Colaborativos) model was applied to three engineering degrees, where the faculty integrated a selection of resources produced by the students with its own.

However, the methodology used significantly increases the number of resources produced by the students based on their own experience. The obtained model is very similar to that proposed in organizations; namely, the student becomes a producer of knowledge. You could say that if students continuously produce knowledge in a given subject, eventually there is an overproduction of knowledge, and that knowledge cannot be selected by teachers as a resource to provide more selective training resources. However, that knowledge can used by the individuals of the organization (in this case, students of given subjects) where such knowledge is useful.

This research suggests that knowledge that is continuously created by students can be selected, classified and organized in such a way that it becomes organizational knowledge, and other students can use it as supplementary material, that is, they use it voluntarily and in addition to resources that the faculty selects. The aim of our work is to promote a methodology that transmits knowledge between peers and improves their outcomes.

This work is included in a previously initiated action-research. Its main objectives are (1) transform the knowledge produced by students within organizational knowledge through a knowledge management system (KMS), (2) understand student perception of the use of such knowledge in a particular subject and (3) measure the impact of that use on their learning outcomes.

In Section 2, we describe the conceptual model within which this work is included. In Section 3, we continue describing the context in which this research is applied and the research methodology used. In Section 4, we support a quasi-experimental study conducted to compare the results between the experimental and control groups and we expose the main results found in this work. Section 5 offers conclusions and a discussion.

2. Conceptual Model

This research integrates the action-research model proposed by Lewin [10] and adapted by Fidalgo et al. [8], adding some improvements (stages II and III) resulting from our experience of action-research. In this model, a KMS called BRACO is the engine that keeps knowledge flowing between the different stages of the action-research. The action-research model consists of three interconnected stages, as shown in Figure 1.

Stage I. *Creation of learning content by students with a teamwork methodology.* In this phase, students create knowledge from their experience of the learning processes of a particular subject during the different phases of the method Comprehensive Training Model of the Teamwork Competence (CTMTC) [11] for the development of the teamwork competence (hereinafter TWC).

Stage II. *Creation of organizational knowledge.* In the previous model, this stage was called 'Management of the created knowledge in a KMS'. This phase has changed; not only does storing individual/group knowledge occur in the KMS, it also becomes organizational knowledge. Students show the acquired experience and associate an ontology that defines source, course, subject, type of resource and themes with which the subject is related. BRACO [8] is based on the Classify, Search, Organize, Relate and Adapt (CSORA) method [12]. Teachers select some resources from students that are included in BRACO and integrate them with their own resources. Such knowledge is incorporated into a learning management system (LCMS) that will be accessible to the students in subsequent courses. Likewise, BRACO organizes and simplifies a search system to access all the resources generated by the students. All knowledge of BRACO selected or not by teachers to the LCMS, is permanently accessible to the students who generated it as well as those who used it. This ensures that, in future, any student involved in the research experience has access to newly generated resources.

Stage III. *Improvement in learning from the corporative knowledge.* Previously, this phase was called 'Reuse of BRACO's content and evaluation of impact'. This stage was based on the use of BRACO resources, but now the use of resources created by the students is done by using an LCMS system, and the BRACO system is used as supplementary material.

During each semester, the students went through three stages of the model, which are undergone again in the subsequent year. This action causes a continuous increase of knowledge generated by students and thus organizational knowledge. This model is based on the knowledge spirals of Nonaka and Tackeuchi [4]. In this case, the interaction between the various phases of each spiral (creation-consolidation-distribution-combination) increases organizational knowledge, as shown in Figure 2-A. Figure 2-B shows the spiral of increasing knowledge in this research model. The different stages of action-research interact through a spiral where more knowledge is created as it progresses. This evolution is represented by an inverted cone [8], showing growth knowledge from the bottom to up. Each cross section in the cone forms a circle whose area contains the knowledge accumulated (knowledge circles) in each academic semester.

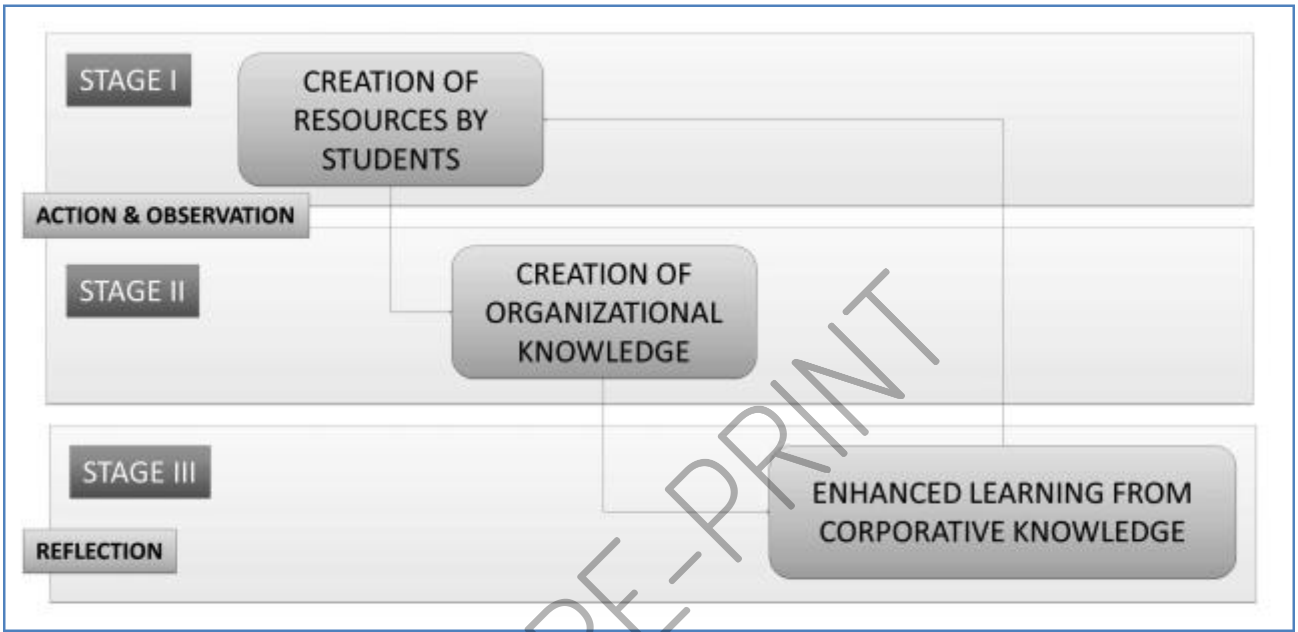

Figure 1. Action-research model.

Previous research has shown that BRACO is a system capable of organizing individual knowledge and transforming it into corporate knowledge; in turn, such knowledge is usable by individuals in organizations, such as educational organizations around the educational innovation theme [13]. This model is based on the integration of the two spiral of the Nonaka model [4]: the epistemological spiral (interaction between tacit knowledge, characteristics of the individual and explicit knowledge that is external to the individual) and the ontological spiral (conversion of personal knowledge into organizational knowledge and vice versa). BRACO allows interaction between the two spirals. In the epistemological spiral, an ontology is created and generates the classification and organization system of knowledge, which increases with each stage of this action-research, since it depends on the type of knowledge created by students. Furthermore, this phase produces the ontology used by the ontological spiral, which is responsible for organizational knowledge creation and its reuse to produce new knowledge.

3. Research Methodology

The empirical study was conducted at the Technical University of Madrid with students studying "The Fundamentals of Programming" (hereinafter FP) in the first half of course 2015-16 in biotechnology degree. The resources used in the study were created by students of the same subject in the first half of 2014–15 and also in "Computers and Programming (hereinafter C&P) in the second semester of the degree in energy engineering in the same academic year. Both subjects share a transverse competency because TWC is performed.
This paper presents a quasi-experimental methodology [14] that is applied to test research objectives because we cannot randomize the groups that participate in the research. We selected two groups: an experimental group (EG) and a control group (CG). The equivalence of both groups is explained in Section 4.1.
Our working hypotheses are:

- H1: Students that are using BRACO get better scores than the others.
- H2: BRACO improves student satisfaction with the subject.

Both groups had the same teachers for each subject, with the same methodology and the same teaching resources; however, only EG used the resources stored in BRACO as supplementary material.

The phases of this research are:

- Phase 1- Provision of organizational knowledge
- Phase 2- Experimentation
- Phase 3- Qualitative and quantitative evaluation

3.1 Phase 1- Provision of organizational knowledge

During the two semesters of the course in 2014–15, knowledge was generated by students during the development of TWC in relation to individual skills (participation, leadership, monitoring, cooperation, problem management, etc.), group skills (mission and objectives, rules, map responsibilities, planning, execution and storage) and results skills (product or service developed). These resources were included in BRACO with an ontology proposed by teachers and formed from *categories*, which, in turn, were composed of *targets*. The creator students of resources associated each resource (e.g. video with the final presentation of the work) with a set of ontological *targets* previously created; these were related to the origin, academic year, job type, individual skills, group skills in teamwork development, etc. [8-9].

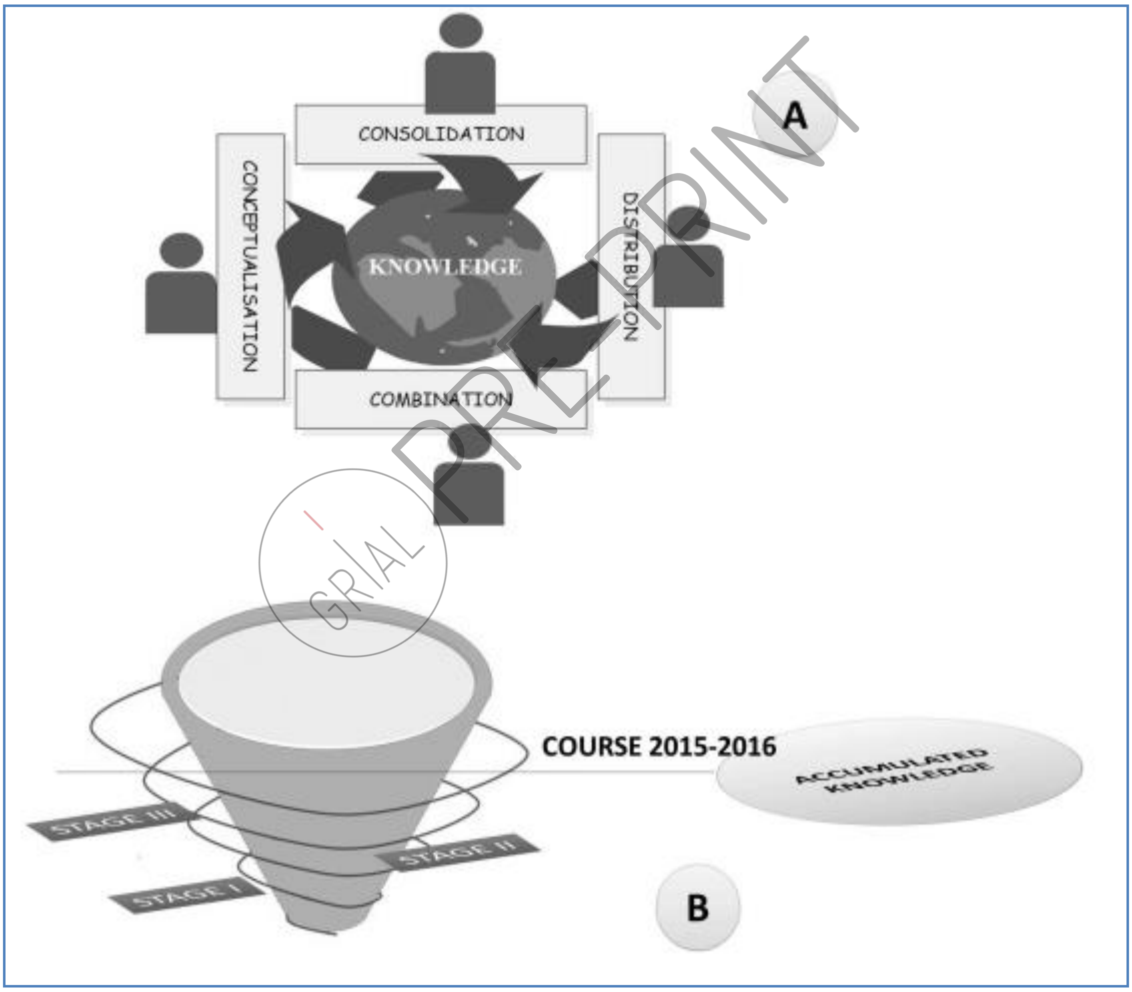

Figure 2. Model based on knowledge spirals.

Teachers have selected from BRACO some knowledge resources for each phase of TWC development. These resources were added to the resources provided by teachers in the LCMS Moodle [15], which gives access to all FP students of the 2015–16 course, regardless of their group membership (CG or EG). The selected content could be used as an example of the work that we expected from the students in each phase of the teamwork (TW); in other words, they could see a video of the expected final product for each phase. The criterion followed in order to select or discard a resource is the final mark obtained in the team and the structure of the work. If the final mark was higher than eight points and their structure met the teacher's expectations, they were selected. EG also accessed all resources included in BRACO. Thus, organizational knowledge was composed of the knowledge generated by students and organized in BRACO, and the resources were made available to students through Moodle.

3.2 Experimentation

From the conceptual point of view, each spiral began at stage I and ended at stage III, but from the point of view of students, the spiral began in stage II and ended at stage I.

Resources created by the students of FP in the first half of 2014–15 (videos mostly), which teachers selected and organized in BRACO, corresponded to the first spiral of the research-action. The second spiral started in the second half of the same year, 2014–15, when students of C&P included the resources created (more varied than the previous ones, with examples of preparation and even results of phases) in BRACO [9].

The third spiral began during the first semester of the academic year 2015–16. At that time, all the resources generated by students in the previous two spirals were included in BRACO. This study explores stage II and III of spiral 3.

3.3 Qualitative and quantitative evaluation

Qualitative assessment was based on a questionnaire conducted by students who used the resources created by other students in the 2015–16 course. The measured items included the TWC training process in both groups, student perception of the learning method, the difficulty of the subject, working time employed and faculty. If there were significant differences in these aspects, this could distort the quantitative results from CG and EG. For example, if the students of EG has devoted more time to learning than CG, learning outcomes not only depended on the use of the resources available in BRACO but also in the variable—time spent learning.

The measured items also included the perceptions of EG of BRACO's ease of use and its impact on their understanding of the tasks and perceived complexity.

The qualitative result will be presented in a future work.

The quantitative evaluation is based on the final grade obtained by the teams. The final mark obtained for teamwork in both groups was compared. The final grade was given individually to each member of the team for the development of the individual, the group and their competences.

This questionnaire was built on the CTMTC method [16] and added some questions suggested by a panel of experts. We used Cronbach's alpha to validate the resultant test, obtaining an overall score of 0.876, which show it had validity.

4. RESULTS

EG was composed of 59 students, and CG was composed of 53 students. The two groups were not randomized, although the students were chosen by according to the scholar schedule. Therefore, we had two natural groups, and the search technique used was a quasi-experimental design.

The results are grouped into four sections:

4.1 Equivalence between the participants in EG and CG.

4.2 Equivalence of the learning process between EG and CG.

4.3 Perception of EG on the use of BRACO.

4.4 Impact on learning in EG and CG.

In order to measure the first three sections, a survey was used. We did not use the same survey for both groups. EG had 27 questions, and CG had 23 questions; 22 items were common to both groups. From the surveys collected, we obtained 54 valid responses from EG, and 41 valid responses from CG. This meant we had a participation rate of 91% in EG and 77% in CG. For the fourth section, the final grade obtained by each member of the teams was used.

4.1 Equivalence of the experimental group and control group

The first step was to verify that the variables used to compare if EG and CG were equivalent, respond to a distribution of normal probability. The Shapiro-Wilk test told us that they were not distribution of normal probability (p-value>0.01).

The second step was to decide if we should use statics parametric, since the population variance was unknown, most variables were categorical and sampling was not random. We concluded that the type of analysis to be performed was nonparametric.

Finally, the variables used to check that both groups were equivalent included: age, gender, time spent in college and qualifying university entrance (see Table 1 for results). All variables studied had a p-value>0.01, so we cannot reject the null hypothesis of equality between the means of both groups.

Table 1: Results of the comparison of the control variables in EG and CG

Variable	Mean EG	Mean CG	Test	Result
Q22 - Age	18.16	18.35	Wilcoxon	p-value=0.062
Q23 - Gender	70.3% Female	60.9% Female	Proportionality	p-value=0.3716
Q24 - How many academic years, including the current one, have you been in college?	1.02	1.08	Wilcoxon	p-value=0.1022
Q25 - What is your university entrance grade?	12.6	12.4	Wilcoxon	p-value=0.1477

The equivalence between the classificatory variables in both groups did not guarantee the equivalence of the groups with respect to the dependent variable, but it assured us that we did not run the risk of internal selection [17].

In the next four subsections, we analyse in detail the variables shown in Table 1.

4.1.1 Question Q22. Age

The average age of EG was 18.16 years with a standard deviation of 0.72. In CG, the mean was 18.35 years with a standard deviation of 0.53. A Wilcoxon test was made to check the equivalence between both groups: p-value=0.062 (>0.01). These results did not reject the null hypothesis that the mean of both groups was equal.

4.1.2 Question Q23. Gender

A proportionality test was made in order to show that both groups had the same proportion of men and women (Table 2): p-value=0.3716 (>0.01). This result did not reject the null hypothesis that the mean of both groups was equal.

Table 2. Proportionality in gender

Female EG	Female CG	Male EG	Male CG
38	25	16	16
70.3%	60.9%	29.7%	39.1%

4.1.3 Question Q24. Years at university

The mean of years at university for EG was 1.02 with a standard deviation of 0.27. In CG, the students had a mean of 1.08 and a standard deviation of 0.33. A Wilcoxon test was used to check the equivalence between both groups: p-value=0.1022 (>0.01). This result does not reject the null hypothesis that the mean of both groups is equal.

4.1.4 Question Q25: University entrance grade

Finally, with respect to the variable university entrance grade, EG average was 12.6 with a standard deviation of 0.76. CG average was 12.4 with a standard deviation of 0.99. This established equivalence between the two groups in the Wilcoxon test" p-value=0.1477 (> 0.01). This result does not reject the null hypothesis of equality between the two groups.

4.2 Equivalence of the learning process between EG and CG

The aim of this section is to ensure that during the process of teaching/learning, EG and CG received the same incentives and that the perception of effort, time and learning methodology was the same in both groups. We used 12 questions, 22 of which were repeated in tests of both groups. These were subdivided into 45 sub-questions. A nonparametric technique bilateral Wilcoxon test was used for both samples. Table 3 summarizes the results for each question. All questions are rated on a 5-point Likert scale (1-total disagree, 2-disagree, 3-neutral, 4-agree, 5-total agree).

Table 3. Students profiles

Question	*Mean EG*	*SD EG*	*Mean CG*	*SD CG*	*p-value*
Q01 Indicate your agreement with the following statements about your learning from the teamwork.					
Q01_1 Teamwork on the subject seemed intellectually stimulating.	3.425	0.923	3.512	1.003	0.5696
Q01_2 I learned teamwork skills that I consider valuable	3.888	0.945	3.731	0.895	0.3128

Q01_3 My interest in working as part of a team has increased my appreciation of the experience.	3.388	1.017	3.292	0.901	0.6404
Q01_4 I learned and understood the skills that make support more effective teamwork.	3.981	0.879	3.853	0.853	0.391
Q02 Indicate your agreement with the following statements about your tutor during the teamwork.					
Q02_1 The teacher was accessible.	3.666	0.890	3.365	1.089	0.1496
Q02_2 The teacher effectively addressed me when I asked for help or advice on work.	3.777	0.793	3.536	1.051	0.3128
Q02_3 The teacher was available for tutoring on teamwork.	3.759	0.775	3.243	0.942	0.0029
Q02_4 The communication style made tutor sessions and activities entertaining.	3.629	1.051	3.609	0.996	0.7398
Q03 Indicate your agreement with the following statements about the organization of the teamwork.					
Q03_1 The teamwork methodology was clearly explained before starting work.	3.240	1.008	3.024	1.083	0.2675
Q03_2 The tools (forums, Wiki, Dropbox) used by the team were appropriate and easy to handle.	4.018	0.835	3.829	0.997	0.4105
Q03_3 Exposure and correction of class work improved team performance.	4.111	0.768	4.073	0.720	0.6549
Q04 During the teamwork, you developed a calendar and a map of team responsibilities, you were involved in discussions team on forums, you collaborated in the creation of the Wiki and shared documents of interest in Dropbox or Google Drive. Choose your level of agreement with the following statements about these resources.					
Q04_1 The calendar of activities of the team was valuable for organizing different tasks.	3.703	1.039	3.609	0.770	0.2164
Q04_2 The map of responsibilities was valuable to know who was in charge of each task and each deadline.	3.833	0.884	3.853	0.792	0.9252
Q04_3 The forums were valuable for collecting the ideas of the debates and the most important team decisions.	3.648	1.151	3.560	1.119	0.6973
Q04_4 The Wiki-Moodle was valuable for gathering all the information for team organization and coordinate tasks.	3.759	0.888	4.048	0.739	0.0913
Q04_5 Dropbox/Google Drive was valuable for sharing documents relevant to the teamwork.	4.425	0.791	4.024	0.790	0.0035
Q04_6 Generally, the teamwork method used allowed me to track the work and the progress of the task.	3.888	0.883	3.853	0.760	0.5789
Q06 Indicate your agreement with the following statements about the contents of the page included in Moodle 'Examples of final results of team work', which was created by biotechnology students in the previous year.					
Q06_1 I saw this page before doing teamwork.	4.314	0.639	4.170	0.833	0.5005
Q06_2 The work on this page was useful for deciding the theme of the work of my team.	3.814	0.972	3.585	1.071	0.2978
Q07 Indicate your agreement with the following statements about the videos page Moodle 'Teamwork. What is evaluated and how to edit a Wiki Moodle' to show different aspects of teamwork.					
Q07_1 I watched the videos.	4.351	0.780	4.560	0.593	0.1904
Q07_2 I found the videos useful for the further development of my teamwork.	4.074	0.797	3.780	1.060	0.2352
Q14 Your work in the team has been evaluated on individual, group and outcome evidence. Choose your level of agreement with the following statements.					
Q14_1 The evaluation system of teamwork is good and proper.	3.814	0.825	3.560	0.923	0.0824
Q14_2 The evidence used (interventions in the forum, activity on the Wiki and store files) to evaluate personal responsibility reflected the real work of each person on the team.	3.166	1.177	3.487	0.897	0.1724
Q15 Indicate the total number of hours you invested in making each phase of teamwork (1-less than an hour; 2-between 1 and 3 hours; 3-between 3 and 5 hours; 4-between 5 and 7 hours; 5-more than 7 hours).					
Q15_1 Hours spent in the mission and objectives phase	2.592	0.942	2.609	0.833	0.6198
Q15_2 Hours spent in the regulations phase	2.388	1.035	2.390	0.891	0.9423
Q15_3 Hours spent in the map of responsibilities phase	2.888	1.127	2.829	0.997	0.8015
Q15_4 Hours spent in the schedule phase	2.777	1.058	2.804	1.005	0.9875
Q15_5 Hours spent in the execution phase	3.981	0.921	3.658	1.039	0.1653
Q15_6 Hours spent in the storage phase	3.203	1.139	3.097	1.135	0.6443
Q15_7 Hours spent in the final result phase	3.777	1.207	3.902	1.090	0.689
Q16 Express your level of agreement with the following statements about the teamwork you undertook.					

Q16_1 Generally speaking, the team worked better compared to previous work.	3.592	0.714	3.682	0.819	0.5442
Q16_2 The workload was shared equally among the team members, which means we all worked equally.	3.777	0.984	3.829	0.738	0.9834
Q16_3 The teamwork method prevented shirking responsibilities.	3.981	0.900	4.121	0.713	0.5499
Q16_4 We passed deadlines and did the job at the last minute.	2.666	0.931	2.878	1.208	0.3625
Q16_5 The quality of the work we did was better than in previously work conducted in other subjects.	3.500	0.795	3.439	0.708	0.6622
Q17 Express your level of agreement with the following statements about the teamwork method that we implemented for this subject.					
Q17_1 It should be applied at the work of other subjects.	3.259	0.828	3.317	0.933	0.6084
Q17_2 Compared with work done previously, the method used in this subject was better suited to working together in a professional way.	4.129	0.728	3.926	0.877	0.2542
Q17_3 I will to use the techniques and tools in my next academic teamwork lesson.	3.814	0.802	3.658	0.990	0.6803
Q27 In your opinion, what is the degree of relevance of the 'know how' of the team in your training as an engineer?	4.518	0.665	4.414	0.631	0.3248
Q28 Express your level of agreement with the following statements about your personal impression regarding teamwork					
Q28_1 Teamwork is usually stimulating	3.574	0.860	3.658	0.911	0.5225
Q28_2 I like working with my colleagues. I am very sociable.	3.703	0.815	3.780	0.880	0.4792
Q28_3 I learn more working as a team than alone.	3.666	0.951	3.439	1.001	0.2031
Q28_4 I prefer to do individual work instead teamwork.	3.203	0.978	3.073	1.191	0.8071
Q28_5 I can get by easily doing teamwork.	3.222	0.816	3.170	0.771	0.6429
Q28_6 I usually waste more time when work is done on a team.	2.944	1.017	2.926	1.034	0.9718

The variables allowed us to compare if EG and CG were verified in order to know if they responded to a distribution of normal probability. The Shapiro-Wilk test indicated that they were not normal (p-value>0.01). In addition, the variance of the population was unknown; all variables were categorical, and sampling was not random. Consequently, the type of analysis that must be performed is nonparametric.

As seen in Table 3, there are only two variables in which the mean of both groups is different (Q02_3 and Q04_5). We will look at each of these cases.

4.2.1 Question Q02_3 Teacher was available for tutoring on teamwork

This variable had a p-value=0.0029, <0.01, allowing us to reject the null hypothesis of equality of means in both groups. The average score for EG was 3,759, with a standard deviation of 0.775; the average CG score was 3,243, with a standard deviation of 0.942.

4.2.2 Question Q04_5 Dropbox/Google Drive was valuable to share documents relevant to the teamwork

This variable had a p-value=0.0035, allowing us to reject the null hypothesis of equality of means in both groups. The average score for EG was 4.425 with a standard deviation of 0.791, and the CG average was 4.024 with a standard deviation of 0.790.

4.3 EG perception on the use of supplementary material through BRACO

Specific questions about the use of BRACO were asked of EG in order to get their perception of the use of BRACO. This test contained three questions with 14 sub-questions. Tables 4 and 5 show the results of each of the questions. Q08 had four categories (none, 2–4, 5–7, more than 7). Q09 was rated on a 5-point Likert scale (1-total disagree, 2-disagree, 3-neutral, 4-agree, 5-total agree). Q10 was a yes or no question, where yes received the score of 1.

Table 4 shows that 45% of students consulted 5–7 BRACO resources, which are above initial expectations because it was optional material.

From Table 5, EG students who used BRACO considered easy to use, with an average score of 3,759. Students found BRACO useful for carrying out each phase of the work, yielding an average of 3.71 in questions on the perceived usefulness of BRACO. A value of 3.96 was obtained for that question, indicating its usefulness in understanding work regulations. From Q10 in Table 6, 75.92% of students said that the BRACO content helped them to know what they had to do in the different phases. Secondly, 59.25% of students indicated that BRACO served to create new resources.

Finally, 48.14% of the students believed it helped them to understand the teamwork method applied during practice. These results lead us to think that students had a positive perception of BRACO, which proves hypothesis H2.

Table 4. Number of resources consulted in BRACO

Number of resources	0	2 to 4	5 to7	>7
Q08 - Denote the number of resources found through BRACO that you viewed	4%	31%	45%	20%

Table 5. Perceived ease of use of BRACO

Q09_1 It was easy to access BRACO resources?	**3,75925926**	**0,88882337**
BRACO was useful in the phase:		
Q09_2 - Mission and objectives	3,94444444	0,87774726
Q09_3 - Regulations	3,96296296	0,91037962
Q09_4 - Map of responsibilities	3,7962963	0,93928173
Q09_5 - Schedule	3,72222222	0,94002542
Q09_6 - Execution	3,72222222	0,95988731
Q09_7 - Storage	3,11111111	0,90421793
Q09_8 - Final result	3,74074074	1,16853699

Table 6. Perceived utility of BRACO

Question	mean	sd	Percentage
Q10- BRACO content:			
Q10_1- helped me to know how to do the different phases	0,75925926	0,43154768	75,92%
Q10_2 - helped me to make the teamwork.	0,14814815	0,3585825	14,81%
Q10_3 - gave me ideas to create resources.	0,59259259	0,49596555	59.25%
Q10_4 - helped me to create new ideas.	0,18518519	0,3920952	18.51%
Q10_5 - helped to understand the teamwork method.	0,48148148	0,50434866	48.14%

4.4 About the learning impact

In this section, we use the final individual marks obtained by students in the development of TWC. These are obtained as a measure of the impact of the methodology used on student learning [18]. Table 7 shows the results for both groups.

Table 7: Individual marks obtained for teamwork

Question	Mean GM	SD GM		Mean GT	SD GT	p-value
Mark obtained by the student for teamwork	25.05	4.07		20.97	4.61	0.0009

This variable has a p-value=0.0009, allowing us to reject the null hypothesis of equality of means in both groups. The average obtained for EG is 25.05 with a standard deviation of 4.07; the average for CG is 20.97 with a standard deviation of 4.61. Figure 3 shows the grades of EG and CG. Although the average of both groups is similar, it isn't equal for the probability distribution. In the case of EG, which used BRACO, the results are clustered around highest grades, but for CG, which did not use BRACO, they are clustered in the lower ratings. This result strongly supports hypothesis H1.

Sein-Echaluce Lacleta, M. L., Fidalgo-Blanco, Á., Esteban-Escaño, J., & García-Peñalvo, F. J. (2017). The Learning Improvement of Engineering Students using Peer-Created Complementary Resources. *International Journal of Engineering Education (IJEE), 33*(2B), 927-937.

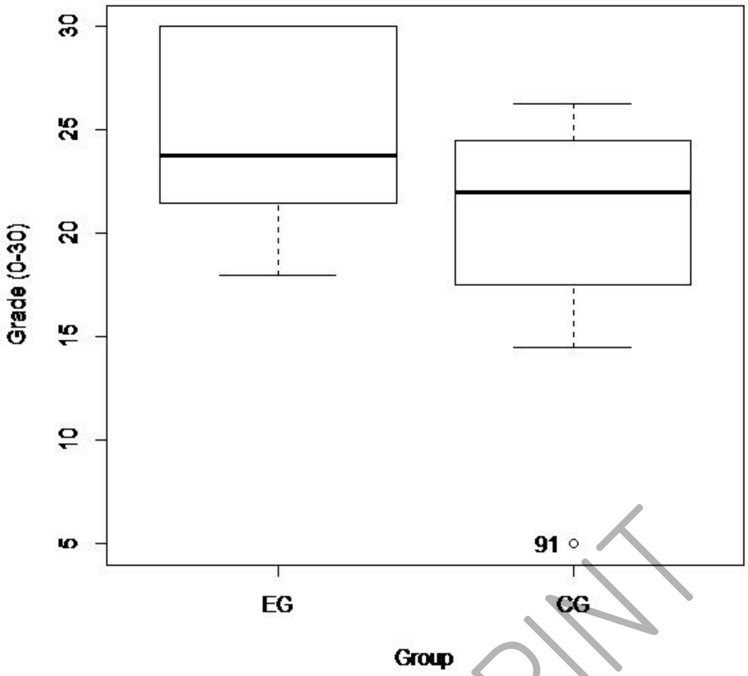

Figure 3. Boxplot diagram with grades obtained in EG and CG.

5. Conclusions

We used variables associated with persons studied (age and gender), the time spent at the university and the university entrance mark. All variables have a p-value>0.01; therefore, we can say that both groups are equivalent.

To validate the impact on learning after the use of complementary resources, we checked that both groups had the same perception of the difficulty of the learning process. Otherwise, we could not obtain reliable results on the impact on learning outcomes. In both groups, the faculty was the same and used the same resources (generated by teachers and a selection of resources generated by students).

In the group of questions Q01 to Q04 and Q14, learning-related variables were measured: stimulus received, learning result, interest, teacher roll, learning method and the resources available in the system LCMS consulted. In 17 of the 19 questions, we found a p-value>0.01, which means that perception about learning received was equal in both groups. There are two cases where there was no equivalence: the availability of the teacher during the tutorial (Q02_3, Table 3) and the utility of a software tool in the storage phase (Q04_5, Table 3). The first difference may be due to the tutorial method used, since all questions were performed online. However, some teams requested and conducted tutorials face-to-face, which can alter the sample. Regarding the perceived usefulness of the storage phase, this phase coincides with the phase in which the experimental group did not perceive utility at all (Q09_7). Another group of questions focused on the time allocated to learning and resources consulted in the LCMS system (Q06, Q07 and Q15). In all cases, we found equivalence between the two groups. The remaining questions (Q16, Q17, Q27 and Q29) referred to the way that students worked in their own team. Again, the results had a p-value>0.01. Therefore, it is concluded that the perception of the learning method was equivalent for both groups.

Thus, the equivalent of EG and CG is consistent, from the sample of students to the learning process perceived by its members.

Concerning the use of supplemental material composed of the resources generated by students in previous years, EG and CG used the knowledge provided by teachers through an LCMS system, which consisted of a selection of resources generated by students from previous years and from the teaching team. Moreover, EG was able to use all the knowledge generated by students the previous year as complementary material in BRACO.

The first objective of EG was based on knowing if the students were going to use the knowledge contained in BRACO, as it was complementary and non-compulsory. In EG, 96% of students used the material, and 65% used more than five resources. The average resources used per pupil was 2.83, which means that team (six members) used an average of 17 resources, which we consider an important conclusion.

Furthermore, students had a wide variety of resources, so we asked them about the relationship between the utility of these resources and the specific phases of the teamwork (this can be considered equivalent to each topic in any subject). In six of the seven phases, students' perceived utility (agree or strongly agree with the utility) was between 65% and 80%. Only in one of the phases (storage) had 39% perceived utility, which may be because no external support was needed to perform these tasks. The main perceived utility was knowing what had to be done at each stage, then understanding the methodology of teamwork and devising ideas for new resources. Consequently, student perception of the effectiveness of learning resources generated by other students was demonstrated and supports hypothesis H2.

After confirming that EG and CG were equivalent, that the perception of the learning method was equivalent in both groups, that EG had a strong perception of the utility of BRACO resources, and that this utility referred to aspects that influence in the learning outcomes, we were able to value the learning outcomes obtained.

The average of the individual rating for learning outcomes, was 25.05 (out of 30 points) in EG and 20.97 (out of 30) for CG. The p-value was $0.0009<0.01$. Therefore, a significant difference in the final score exists in favour of EG because it used the BRACO complementary resources. This result proves there is difference in scores between the groups, which supports hypothesis H1.

In conclusion, we can say that promoting, organizing and providing availability of resources generated by the students of other courses was perceived positively by students and had a significant impact on learning outcomes.

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