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Students' Knowledge Sharing to Improve Learning in Academic Engineering Courses*

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This paper presents an example of scaffolding during the development of an engineering course, in which students are supported by teachers and other students. This proposal covers the benefits of the use of shared knowledge repositories in which content was created by students. Teamwork is the transversal competence that is considered to be the central knowledge topic. The cooperation among students through teamwork methodology has generated more than 500 learning resources and a knowledge management system, BRACO, which has been created with these resources to manage information and conduct searches according to each student's profile and needs. The generated knowledge spiral is composed of knowledge circles that increase during each iteration of the action-research implementation. The reflection phase of this research consists of the evaluation of the impact on learning for students in the experimental group after using the knowledge resources generated by students in relation with teamwork competence, in contrast with the control group that does not experience this intervention. With regard to the assessments, several surveys and a learning analytics system, this paper explains the underlying methodological foundations and the empirical study. In comparison to the control group, the experimental group obtained better results in relation to indicators of positive learning results, such as student-student interaction, teamwork development and final grades during the teamwork process.

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

1. Introduction

Results from academic courses can improve every time they are taken by means of the tacit knowledge acquired through experience. Knowledge sharing increases creativity by converting the tacit knowledge, embedded in individuals, into explicit knowledge through interaction [1]. When a new cycle of a course starts, teachers often include mainly two types of new knowledge: internal knowledge from their own experience, which was gained from previous involvement with the course, and external knowledge (other courses, books, conferences, etc.) [2]. In [3], those items appear as one of the main information sources of educational innovation for faculty. Furthermore, students are also key to generating new resources during a course, and they gain experience through collaborative and proactive activities. A course's design aims at facilitating the acquisition of skills by students through internal knowledge that is specific to the course (content, notes, examples, exams, etc.) and external knowledge from the educational environment (dependencies training centres, procedures, rules, associations, etc.).

Moreover, the knowledge involved in an academic course is usually managed in Learning Content Management Systems (hereinafter LCMS) [4–6]. Students use cloud web 2.0 tools (cloud computing) with increasing frequency to share learning resources with classmates [7, 8] and frequently they use their mobile phones to access to thereof [9]. These resources can be class notes, solutions to problems, questions and, in general, any useful learning resource. Nevertheless, students normally develop these activities in an informal way [10–12] such as in circles of trust (friends) and punctual circumstances (most commonly when a deadline is approaching). However, better organized initiatives exist, both of the informal type—led by the students themselves [13]—and the formal and framed type, typically within mentorship projects organized by the faculty or the academic institution [14]. The definition of a culture of management and sharing learning content requires, firstly, that individuals generate pieces of knowledge; secondly, the definition of a reward system for the users who create knowledge [15]; and finally, promoting knowledge exchange [16]. This culture has been described in previous studies by this

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research team as promoting knowledge sharing in different contexts: informal learning in the MARIA project, where the knowledge is provided by students' parents [17]; distance learning in an LCMS [18], educational innovation experiences in repository [19], teamwork development [20], academic resources of students [21, 22] and open resources culture [23].

On the other hand, collaborative information created by students during an academic course enriches students' learning and teachers' experience. Schuster says, ''Collaborative document creation enables humans to solve complex problems in a team, to exchange ideas and to benefit from synergistic effects'' [24, p. 1]. In relation with collaborative work, the use of teamwork (hereinafter TW) methodologies has increased exponentially in higher education and is in particular demand from companies. Among TW benefits, the following are emphasized [25]: increased efficiency, greater effectiveness and faster output (through the combination of individual efforts), more thoughtful ideas (from different minds focusing on the same problem) and mutual support and outcomes, which utilize resources more effectively. Many previous studies are focused on different objectives in the use of TW with engineering students [26–28].

Moreover, TW increasingly converges with the knowledge management field, and some authors stress the importance of TW in the conversion of tacit knowledge into organisational knowledge [29]. In educational organisations, the knowledge created by work teams and related to topics of a specific course can improve the number of available resources (educational content) if they are accessible to future students. It is also argued that individuals can improve their abilities to solve unstructured and complicated problems, reduce mistakes and increase learning through knowledge sharing [1]. The methods, based on knowledge spirals, are used to create organisational knowledge and transform individual knowledge into organizational knowledge. Two types of knowledge spirals are considered in these methods: the epistemological spiral (interaction between types of knowledge) and the ontological spiral (interaction between the individual's and the organization's knowledge) [30].

In this study, a framework based on knowledge spirals is built to prove that the use of content created collaboratively by students positively impact learning improvement in other students—in particular, demonstrating that improving students' efficiency in TWC by using knowledge related to TWC that is created by other students is possible. This study combines a cooperative methodology called Comprehensive Training Model of the Teamwork Competence (hereinafter CTMTC)—used for the acquisition of teamwork competency (hereinafter TWC)—with a specific knowledge management system (hereinafter KMS) called CSORA. This combination allows the integration and management of more than 500 educational resources on TWC that were generated by students through a TW methodology and supports their adaptation to different learning requirements and the needs of teachers and students.

This KMS allows teachers to provide this knowledge on TWC to other students to help them perform tasks and learn new skills, concepts or understandings. This structure corresponds to the definition of scaffolding, an effective conceptual metaphor for the type of teacher or student intervention in other students' learning [31]. The concept was defined by Bruner [32] based on the idea of Vygotsky on the zone of proximal development (ZPD), defined as ''the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers'' [33, p. 86]. The task-specific support (in this case, to TWC) is designed to give timely and progressive support to learner needs to complete the same or similar tasks with the TW process later in other courses [34].

This paper studies the student impact on learning with scaffolding that is provided by more capable peers. This fact is shown with a quasi-experimental study involving two groups (experimental and control) and comparing three different indicators between both groups. The first indicator is focused on student-student interactions during TW sessions, which is ascertained by the number of messages in the forum. In that sense, previous work proves a strong positive correlation between student-student interaction and students' final grades for TW development [20]. The second indicator examined in this study is TW development (degree of compliance with the plan recommended by teachers), and the third is the final grade for TWC (in group competence). The teachers obtain these indicators with the assistance of a learning analytics system and through direct observation with the technology used in the TW development.

The following section describes the methodology used in this study. Afterward, the empirical study is presented, and finally the results of this research are presented, followed by the conclusions.

2. Research methodology

An action-research methodology is proposed here because it considers problems of a specific context (such as reusing resources created by engineering students) and collaboratively involves all agents (teachers and students) and includes general steps: planning change, action and observation and reflection of the process and its consequences (such as the impact on learning) [35, 36]. It proposes a methodology that promotes the creation, classification and organisation of both teachers' and students' learning resources during a teamwork process within the same course scope in a timely manner. The teamwork process is monitored with a proactive approach that makes the collaborative generation of resources possible.

In this way, the general research could integrate an unlimited number of action-research iterations that are part of a knowledge spiral that generates knowledge circles during each implementation, resulting in an inverted cone shape (Fig. 1) [37]. The amount of knowledge included in the circles (the transversal section of the cone) increases, improving services and products (ontology and the search engine). The quality of knowledge generated by students is also improved by other students (users of the knowledge). The first circle corresponds to the start of the academic year (semesters 1 and 2) and each circle is linked to the next circle in the same way (semesters 2 and 3) and so on. In the first knowledge circle, Students_1 cooperatively generated knowledge during semester_1, which is used and cooperatively improved by Students_2 during semester_2. While Students_2 create new knowledge, Students_3 use and improve the knowledge generated by Students_1 and Students_2 during semester 3, and so on.

The first iteration of the action-research methodology allows certain questions to be answered, including questions regarding "the types of resources created during the TW session" (with academic, social and service orientations), "how

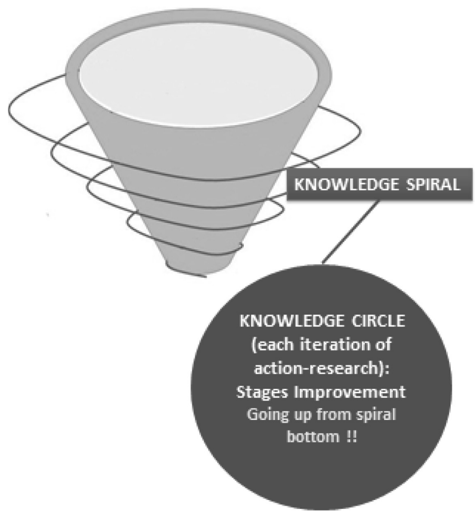

Fig. 1. Knowledge spirals.

to establish a common organisation with the created knowledge for all potential users" and "how to improve educational resources for an academic course with these collaborative resources". These questions have been answered in previous studies [21, 22]. This paper constitutes the reflection part of this action-research iteration and studies whether content created collaboratively by students positively impact learning improvements in other students.

The general research question originates from the following reflection: "Is it possible to improve learning efficiencies by using knowledge created by other students?" In this paper, the following research question will be answered in particular: "Is it possible to improve the efficiency of TWC by using knowledge created by other students in relation with TWC?"

Each iteration is composed of three stages that connect the knowledge created by students through a cooperative method (Stage I: knowledge circle of the spiral), management of that knowledge (Stage II: KMS) and the reuse of content by other students, and the evaluation of the impact on learning of that knowledge (Stage III: empirical study).

Stage I. Creation of learning content by students with a TW methodology.

Students in a course are grouped in work teams. Each team creates resources during the development of the proactive CTMTC method [38, 39] that has been used to promote dynamic, cooperative work teams to train and assess the TWC.

As a reward, the new resources are taken into account in the final evaluation of the course and teachers validate (or not) the resources as educational resources. This stage includes the creation and identification of the resources generated, such as teacher's notes, exam solutions, solved exercises, levelling questionnaires, videos with difficult concepts, useful academic information, web pages, papers, interviews with fellow students, teachers, engineers, professionals in the sector, etc. More information in previous papers regarding the type of resources created by students was identified [21, 22].

Stage II. Management of the created knowledge in a KMS.

The goal of this stage is the management of the knowledge created in the course in a dynamic, flexible and adaptable way that leads to a KMS development. The proposed KMS is based on the CSORA method [40], which allows one to Classify, Search, Organize, Relate and Adapt the resources generated by students. CSORA uses tags to shape the ontology as a search system and provide a final product that is adapted to users' needs [22]. It has been defined, employed and specifically adapted to the strategic environments found in engineering, both by the Ministry of Economy and Competitiveness [41] and the Ministry of Education, Culture and Sports [42]. CSORA is successfully used in the Information Points Network on Research Development and Innovation Activities program, where it has demonstrated effectiveness in search R&D&i projects because the user's search is based on generic search targets without knowing the specific nature of what is being searched [37, 43].

In this case, the ontology (composed of more than 60 tags grouped into 10 categories), corresponding to the resources created by students, was built and justified in a previous paper [21]. The categories identify the context while the tags identify the specific need. The ontology has been assigned to resources created by students and defines the source, type, utility and the activity of the resource in which it was generated. The ontology is based on traditional models used in innovation [44] that have already been tested in educational innovation contexts [45, 46]. The proposed tags are grouped into categories classified as input, process and output. Input includes categories that refer to the knowledge source. Process refers to the academic activities related to knowledge. Output refers to the type of created knowledge: academic support, welcome pack, professional opportunities, etc.

The final product generated by CSORA in this study is the BRACO repository (the Collaborative Academic Resource Finder, or Buscador de Recursos Académicos Colaborativos in Spanish) [22]. BRACO consists of a KMS (to which faculty and students contribute content), an adaptive search engine (used by students and teachers to locate and identify resources) and a set of specific subsystems designed to support various academic activities. The result of the system is that each user can have his/her own organisation and choice of results, depending on the requirements that each user defines and is based on a specific learning need (e.g., preparing for an exam). Users can generate a portfolio (file with editable text) with a selection of resources obtained during the search. Faculty also can organize the search outcomes as a list on a personalized webpage that can be seen by the students. The search structure is shown in a previous paper [21].

Stage III. Reuse of BRACO's content and evaluation of impact.

In this stage, the content created by students_1 (semester_1) during the TW process are reused by students in the next semester in the same or similar courses (students_2) (Fig. 2). Content is provided to students_2 from the BRACO repository. At the same time, students_2 create new resources that correspond to Stage I in the next knowledge circle. Scaffolding represents the transit from Stage II to Stage III as the support provided from students_1 to students_2.

During Stage III, a reflection on the process (the three stages) and its consequences is done to improve the methodology in the next knowledge circle of the spiral, which can inform several studies on the impact on learning, the quality of the generated knowledge, revision of the ontology to improve the adaptive options of the search engine, etc. In this case, the attention is focused on the empirical study of the learning impact on students who are users of the generated knowledge content from previous semester by other students. The correspondence of these three stages of the knowledge spiral and the steps of the action-research (planning to change, action, observation and reflection) is also shown in Fig. 2.

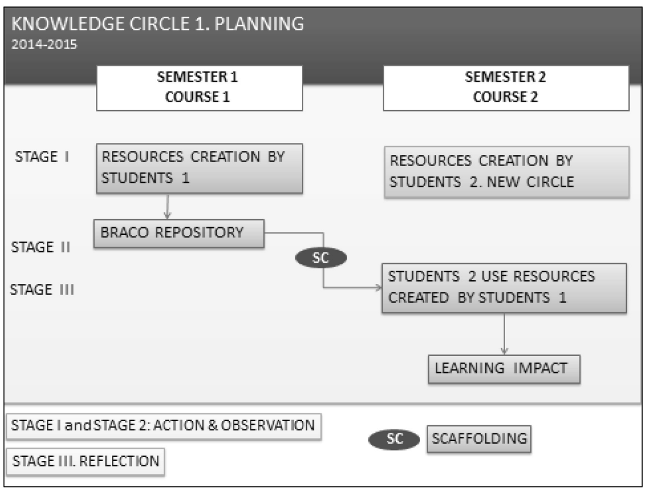

Fig. 2. Action research stages.

3. Empirical study

The empirical study was conducted with the students of the "Computers & Programming" (hereinafter C&P) course from the energy engineering program's first year at the Technical University of Madrid (hereinafter UPM), which occurred in the second semester of the 2014–2015 academic year. Students were divided by the institution into two official groups, GIE1 and GIE2. One group served as the experimental group and the other one served as the control group, and a random sample was not used (which conveys a quasi-experimental design to the study).

This research proves that the two academic groups (GIE1 and GIE2) did not show any statistically significant differences. Both groups took the same tests and used the same methodology and teachers. The innovations of the experiment were applied to the experimental group, and the teachers measured the impact on learning and the comparison between the two groups with a final evaluation.

The phases of this study are the following:

- Choice of experimental and control groups.
- Experimentation.
- Evaluation and cross-check.

3.1 Choice of experimental and control groups

Group selection was conducted with an initial survey and proved that the differences are not statistically significant.

A survey on academic resource sharing habits and their usefulness was conducted with the students at the beginning of the course [37]. The survey is divided into the following sections: student profile (gender, being new to the course or not, age and entrance grade at the university), planning in previous teamwork, training involved in previous teamwork, process for previous teamwork and existing habits for sharing knowledge. The survey was completed by 150 of 167 students from both groups (GIE1 or GIE2).

The degree of significant differences between experimental and control groups are determined by certain variables. The student's entry grade at university was used because the sample is chosen based on new entrance students (Q04) and five questions about previous education on TWC (Q33). Grades are widely accepted indicators of academic success and quality of previous education on general academic knowledge. However, this indicator must be completed with specific knowledge about TWC that students had obtained from previous courses. These indicators, provided by Q04 and Q33, prove that there are no significant differences between the groups with respect to general and specific knowledge included in this research (TWC). The data distribution for those variables is not normal; therefore, a Wilcoxon test for the two samples is used to prove that the differences between the two groups are not statistically significant.

3.2 Experimentation

The experimental group reuses the resources previously created by students (and selected by teachers), and the control group only uses official resources provided by teachers. In this paper, as an initial approach, teachers choose themselves as the best resources by previous students to study the impact on the current students.

Both groups work on TWC with the CTMTC method [38, 39]. One group (control) worked with guides on TW created and provided by the faculty, and the other group (experimental) also worked with supplementary resources that were provided by the faculty, but the experimental group's supplementary resources were created by students from a previous course.

The resources used by the experimental group were created by 107 students (grouped into 18 teams) from the "Programming Fundamentals" course, which is part of the biotechnology degree program at the UPM (first year of the program). They were trained in TWC during the first semester of the 2014–2015 academic year, and the content that they generated during the TW process was described in a previous study [21]. In this study, students of C&P also used resources created in an earlier year (2013-2014). Those resources were described, classified and organized in the BRACO repository according to the stakeholders (course students, external students and graduates) [22]. Although the BRACO repository is available to students, the faculty members select a wide range of content in this cycle and provide them to students in the experimental group through an LMS (Moodle [47]) for students to select the most useful content.

On the other hand, the CTMTC method allows the training and evaluation of individual and group skills during TW development, as well as the evaluation of the final result. This is a proactive method that based on three aspects: TW phases (election of leaders, mission and goals, rules, map of responsibility, planning, implementation and organisation of documentation), collaborative creation of knowledge and cloud computing technologies (LCMS, wikis, forums, social networks and cloud storage systems).

Faculty members continuously monitor team members' collaboration and individual progress through the TW phases and through the cloud technology. This monitoring allows for training assessments by teachers to guide the students' individual learning. At the same time, this method allows teachers to conduct partial assessments in to compose the final summative evaluation of TW [21]. The faculty also provides recommendations for activities that the students should perform on specific dates. When the deadline to perform an activity arrives, a participative classroom session is held and teams present their results. These results are used by teachers as educational resources and examples of good or bad practices. During TW sessions, the teams correct possible mistakes to continue through the subsequent phases of TW process.

The first two activities proposed by teachers include all phases that are part of the TW process until the implementation phase. In activity 1 (for one week), each team must elect their leader, define the work rules and describe the mission and goals. In activity 2, the teams correct previous incorrect actions and generate the map of responsibilities, chronogram and implementation phase. Each team members perform different actions (e.g., election of leaders) and interact through forums and social networks. The results of each TW phase are shown in a private wiki.

The monitoring of the TWC development and implementation is performed by analysing forums and wikis. Teachers collect test data after activity 1 (the day when it is completed and three hours before the classroom session).

3.3 Evaluation and cross-check

The third phase of the empirical study consists of the teachers' evaluation of the following three aspects: work intensity, TWC development and learning outcomes.

- *Student-student interactions in TW* are measured by the number of messages per person in the LMS (Moodle) forum. A previous study shows that the number of messages in the forums, obtained with the Learning Analytics system through the CTMTC method, is related to the acquisition of TWC [20].
- *TWC development.* Teachers evaluate whether each team has performed well or poorly on the tasks in the TW process. The overall continuous assessment processes require the completion of activities on certain dates, and when these processes are cooperative (such as TW), synchrony between the cooperating individuals are required. The development degree of tasks indicates whether the team performing the processes in time and at the right time. It is necessary that the teams respect the deadlines because they have to finish the corresponding tasks before classroom sessions commence.
- *Teachers evaluate learning outcomes of the TW by* assigning grades according to the results of each activity. All three measures are obtained at three points: at the end of activity 1, approximately fifteen days before the deadline of activity 2 and at the deadline of activity 2.

4. Results

In this section, all results are included to select subjects for the experimental and control groups (scaffolding is applied to the experimental group and not the control group), and the results prove that the experimental group demonstrates learning improvement with respect to the control group.

Table 1. Student profile and previous TW training received by participants

Profile			
Questions	**Answers**	**GIE 1**	**GIE 2**
Q04_ Grade obtained in the university entrance exam	Mean Deviation	10.98 1.2	11.10 0.78
Teamwork Training			
Q33 Have you been trained in the following skills or knowledge to develop TW skills? (1 never, . . . , 7 always)			
Q33-a-How to develop a work plan	Mean Deviation	3.50 1.66	3.80 1.80
Q33-b- How to carry out the monitoring of the work processes	Mean Deviation	2.80 1.60	3.17 1.72
Q33-c-The parts of the final report	Mean Deviation	4.00 1.95	4.30 1.70
Q33-d-Explanation of TW characteristics	Mean Deviation	3.82 1.70	4.18 1.68
Q33-e-Planning, task assignment, milestones, schedule, map of responsibilities	Mean Deviation	3.41 1.73	3.67 1.88

4.1 Choice of experimental and control groups

The survey on previous TW experiences was analysed, which examines the student profiles, TW planning, previous TW training and the procedure for doing the TW process previously [32].

89.41% of the GIE1 members (76 of 85) and 89.15% of GIE2 members completed the survey (74 of 83).

Table 1 contains the mean and standard deviations of the GIE1 and GIE2 groups for the six variables considered in this empirical study: Q04 (grades from the university entrance exam) and Q33 (five items regarding previous TW training). The rate of Q04 is 5 to 14 and the rate for items Q33 is based on a Likert scale of 1–7: 1(never), 2 (few times, less than 20%), 3 (sometimes, from 20% to 40%), 4 (half the time, from 40% to 60%), 5 (quite a lot, from 60% to 80%), 6 (many times, more than 80%) and 7 (always).

The Q04 variable (grades from the university entrance exam) and variables Q33 (related to previous TWC training) do not follow the normal distribution in the two groups (the Shapiro-Wilk test). Therefore, the significant differences between groups GIE1 and GIE2 are checked with a non-parametric test for two samples (T. Wilcoxon).

The null hypothesis H0 establishes that the means of all variables considered in this study is equal in the two groups (there are no significant differences between the groups with respect to those variables). The alternative hypothesis H1 states that the mean of university entrance grades and/or TWC training are different in the two groups.

Table 2 shows that the p-value Wilcoxon test for each variable is higher than 0.05, which means that the null hypothesis H0 is accepted; namely, there are no statistically significant differences between the GIE1 and GIE2 groups. After this check, GIE1 is chosen as the experimental group and GIE2 as the control group.

4.2 Evaluation and cross-check

To analyse the intervention effects on the experimental group (with the additional use of BRACO's content, created by other students) and compare these effects with those of the control group, three assessments were conducted during the TW development.

As mentioned previously, the evaluated tasks are grouped into two activities: activity 1 and activity 2. Activity 1 lasts one week and consists of the following tasks: leader election and establishing the mission, goals and policy (operating rules). Activity 2 consists of tasks: creating the map of responsibilities, chronogram and execution. Three assessments were conducted (dates are related to starting TW): the first at the deadline of activity 1 (five days later), the second between activity 1 and 2 (30 days later) and the third at the activity 2 deadline (six weeks later).

Table 2. Wilcoxon test of two samples for Q04 and Q33

Wilcoxon test p-values					
Q04	**Q33-a**	**Q33-b**	**Q33-c**	**Q33-d**	**Q33-e**
0.2339	0.3479	0.2264	0.3402	0.2042	0.4014

The three assessments take into account the following aspects: TW student-student interactions (the number of messages between students in the forum during TW), TWC development (the degree of compliance of the planning recommended by teachers) and final TW grades (the final grade for group competence).

Data are obtained from two sources. Firstly, a learning analytics system [20] allows the faculty to analyse the forum messages (the number of messages per team/individual and team members who are working together). Secondly, the observation of group skills reflected on the wiki and forum threads allows the faculty to ascertain the development and evaluation of each task.

Student-student interactions during TW is measured through the involvement of team members by the mean number of messages per person (Table 3). The experimental group presents higher values. In the first measurement, the average percentage of messages in GIE1 were 55.98% greater than in GIE2; in the second assessment, the average number of messages in GIE1 were 11.78% greater than in GIE2; and in the third assessment, the average number of messages in GIE1 were 16.65% greater than in GIE2. This implies that the experimental group has worked more intensively than the control group.

Regarding *TWC development*, Table 3 shows the evolution of work in the different teamwork phases. The experimental group GIE1 shows a higher percentage of completion than the control group in every task. The difference between the two groups is especially relevant in the execution task. It can be observed that the experimental group GIE1 works more consistently and has progressed further with the task than the control group.

The percentages of final grades are included in Table 4 (grades from 0 to 10; less than 5 means a failing grade). In the evaluation process at the end of each activity, the experimental group had percentages close to 100%. The experimental group has 113.89% more successful members than in the control group in the activity 1 assessment, more than 300% in the second assessment and 83.34% more in the third assessment. In the assessment that took

Table 3. Student-student interactions and TWC development

Activity dates Initial date, assessment date (in bold) and deadline	**End of ACTIVITY 1** 02/16/2015 – **02/20/2015**		**During ACTIVITY 2** 02/20/2015 – **03/15/2015** – 03/27/2015		**End of ACTIVITY 2** **03/27/2015**	
	GIE 1	GIE 2	GIE 1	GIE 2	GIE1	GIE2
Mean of number of messages/person (forum)	8.47	5.43	21.34	19.09	24.93	21.37
Task: Election of leader	83.33%	72.72%				
Task: Operating rules	83.33%	45.45%				
Task: Mission and goals	75%	36.36%				
Task: Map of responsibilities			91.66%	63.36%	100%	100%
Task: Chronogram			50%	45%	100%	72.73%
Task: Execution			25%	0%	58.33%	9.09%

Table 4. Learning results (final grades)

Activity dates: Initial date, deadline, online assessment date (in bold)	**ACTIVITY 1** 02/16/2015 – **02/20/2015**		**ACTIVITY 2** 02/20/2015 – **03/15/2015** – 03/27/2015		**ACTIVITY 2** deadline **03/27/2015**	
	GIE 1	**GIE 2**	**GIE 1**	**GIE 2**	**GIE1**	**GIE2**
Number of teams that did not start the activity	16.66%	18.18%	0%	27.27%	0%	0%
Number of teams that fail the evaluation	25%	54.54%	58.33%	63.64%	16.67%	54.55%
Number of teams that pass the evaluation	58.33%	27.27%	41.67%	9.09%	83.33%	45.45%

place at the intermediate stage (during activity 2), the percentage was higher than 300%. Therefore, these results reinforce the notion that the experimental group GIE1 has a superior final grades average than the control group and is more consistent in terms of work development.

In Fig. 3, the percentages of teams that obtain each grade are given for activity 1 (percentages are used because the number of teams are different in GIE1 and GIE2). It is shown that the experimental group GIE1 has more successful members with better grades because the graph is shifted to the right. For example, failed members (e.g., grade 2) represent 27.27% in the control group GIE2 and 16.67% in GIE1. Fig. 4 shows that the experimental group (GIE1) has a higher percentage of teams than

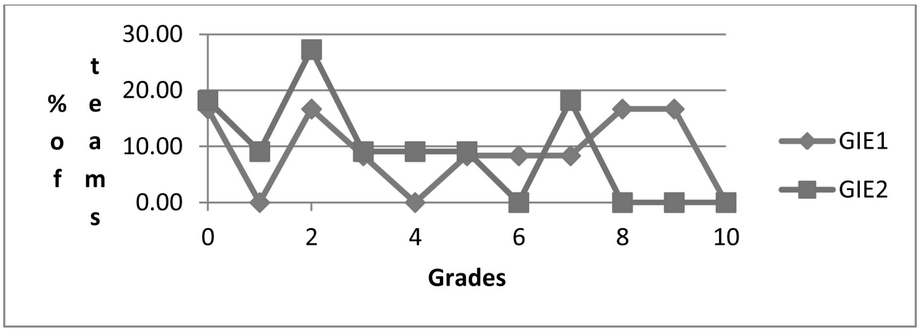

Fig. 3. Percentage of teams per each grade in activity 1.

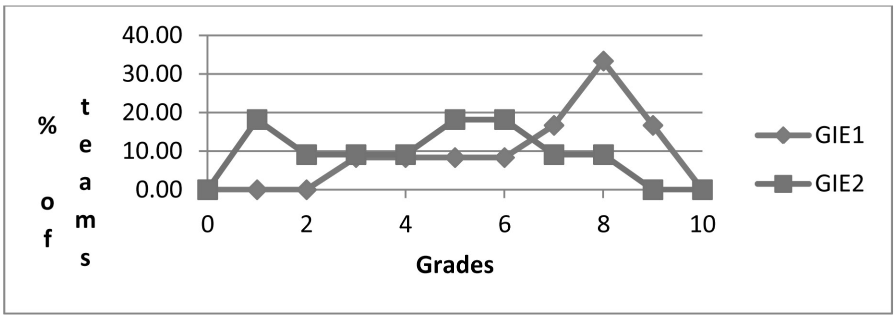

Fig. 4. Percentage of teams per each grade in activity 2.

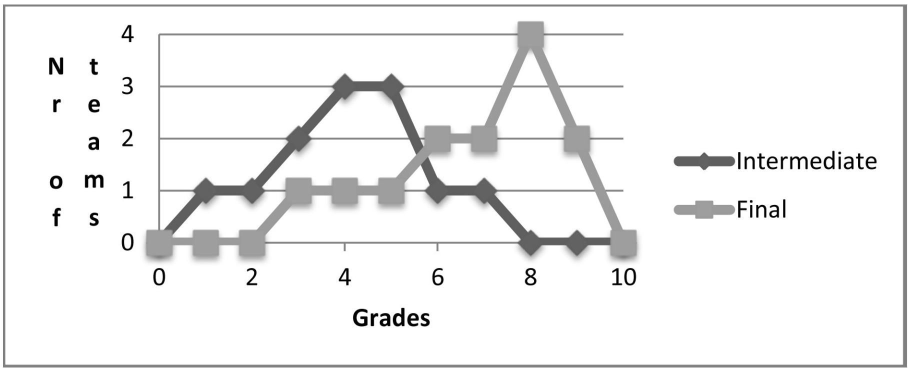

Fig. 5. Activity 2 evolution for GIE1.

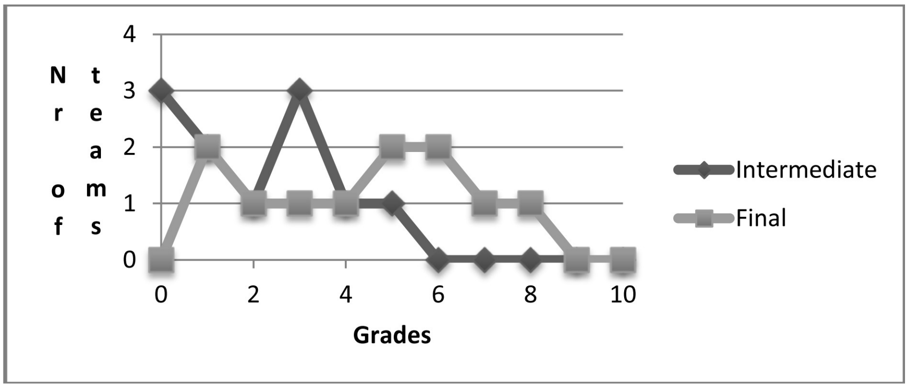

Fig. 6. Activity 2 evolution for GIE2.

GIE2 that passed the evaluation at the end of activity 2, and their grades are also higher. The opposite case occurs for the failed teams.

Figure 5 shows that the experimental group GIE1 completed the work in a continuous and effective way in the intermediate and final assessments of activity 2. The right shift of the graph shows that there is adequate progress and the number of successful grades (greater than or equal to 5) increases. Fig. 6 shows that GIE2 teams did not work continuously, and a high number of teams did not even begin activity 2 and most teams have failed both assessments of activity 2 (intermediate and final). This means that most teams began working in the final days by leaving most tasks to the end. The final assessment presents better results than the intermediate assessment but the number of fails is still significant.

5. Discussion

A repository (BRACO) of content created by students is the technological support for scaffolding. This KMS is based on ontologies that allow an adaptive search of resources according to the preferences and needs of users (teachers and students), allowing personalizing searches for content, with additional benefits for student learning [18].

This research promotes the reuse of content that was created collaboratively by students with a TW methodology; its improvement of skills has been studied in other papers [20, 21].

The empirical study presented here proves the positive impact on student learning during TW development by using content created by other students. The study proves that the experimental group has obtained better results in three aspects:

1. Student-student interactions during the TWC process (a strong and positive correlation with final grades has been proved in [20]).
2. TWC implementation, by means of the rhythm of consecution of the different TWC phases and the degree of compliance of the planning recommended by teachers. It confirms that good learning habits, such as the regularity of work, influence final learning results positively [48].
3. Final grades of TW process, which are the indicators that are widely accepted by educational institutions indicating that acquisition of abilities and/or knowledge has been done.

These facts give an affirmative answer to the research question: Is it possible to improve the efficiency in TWC by using content created by other students in relation with TWC? The efficiency level has been obtained for the experimental group in the final grades and the rhythm of TWC development, which are higher than in the control group and higher than the expected results by teachers.

TW is the topic selected for this empirical study in terms of content created by students and included in BRACO because TW is one of the most sought-after professional competences, specifically in engineering students [49–51]. The transversal character of this competence ensures the transferability of this skill to any course or knowledge area that uses a TW methodology.

This example of scaffolding utilizes the knowledge of experts (students from previous courses) to help students with the acquisition of skills in TWC. Next, knowledge spirals that build subsequent scaffolds will increase the amount of content created by students and their inclusion in BRACO and include information on the learning impact of content more specific to the courses (non-transversal as TW), revision of the ontology used to manage the content to improve the adaptive characteristics of the search engine, etc. Another proposal is the promotion of the direct use of the BRACO repository by the students, who are users of the content. In this way, students may access the most adapted content according to their preferences and needs and identify the most useful content.

The proposed BRACO repository removes spatial and temporal obstacles (the repository can be used inside and outside the university). It also grants permanent access to resources, which is not a common method of structuring courses at the beginning of the academic year (the typical behaviour is to restart the course every year, and previous students of the course cannot re-enroll). This idea would offer a large amount of future applications, such as long-life learning for students who have made contributions to some knowledge spiral in research or for mentoring activities (for mentors to support future students).

In this study, the faculty also promoted good practices in terms of intellectual property, citations, etc. through dedicated sessions in the classroom. In future courses, this training will be increased through direct talks with experts on this topic and the written promise of the students to protecting their own and others' knowledge.

6. Conclusions

After analysing the results of this experience, we can conclude that the use of the contents created by the students as learning resources has a significant impact in the teamwork competence as learning outcome.

Specifically it is important to underline the following specific aspects. First, the interaction among the students increases. Students who have participated in the experimental group show a greater number of interactions through messages in the forums. Second, there is an improved regularity in the continuous development of the tasks. Students who have participated in the experimental group have made the different phases of the teamwork continuously, taking more regularity both in the development of the assigned tasks and in the completion of thereof. And, third, there exist an increment in the final grades. Students who have participated in the experimental group have had better academic results in the evaluation of the teamwork competence. The obtained results improve both the number of successful students and the quantitative grade thereof.

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