Exploratory study about team-effectiveness of engineering students teams assigned by the instructor to have diversity of roles

MPBL-AUU

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Contents

Abstract

Although many investigators support the instructor-assigned teams, in the usual teaching practice in project-based learning environments, the formation of the team for the project is often left to the self-selection of the students. The work of this thesis, of experimental exploratory nature, was about engineering students' teaming-effectiveness, after working in project teams instructor-assigned, based on have role diversity in the team by applying a team role's questionnaire, and also, after receiving specific instruction about teamwork. The participants in this study were 77 third-year engineering students attending a manufacturing processes course during 2018-01 semester. Teams of 4 to 5 students developed a course project throughout the semester. A questionnaire was implemented to obtain, confidentially, an assessment of teamwork, a self-assessment and a peer assessment of the work of each one of their colleagues. Teams were asked to write a process analysis (reflections on project management, on the individual and group learning processes, and recommendations for their future work in teams). This study was done with a qualitative approach. The salient themes found were: interdependence and team structure, shared mental models, communication inside the team, conflict management, social loafing and scheduling conflicts. The constructs of team spirit and social support were no detected. As far as the author know, there is scarce research on the results of the team-forming method selected, based on mixing the roles that spontaneously assume the students, when developing team projects in engineering education settings.

Key words

Manufacturing engineering; Project-Based Learning; Instructor-assigned teams; Team roles.

1. Introduction

1.1. Context of the problem

Complex projects, developed by work teams, are the predominant practice in contemporary engineering. (Natishan, Schmidt, & Mead, 2000). Consequently, teamwork and communication skills are, in addition to scientific-technical skills, indispensable attributes in the engineering job market. In response to these demands, engineering schools are increasingly accentuating the experiences and learning outcomes of teamwork of their students (Patil & Codner, 2007). But, on this regard Shuman, Besterfield-Sacre & McGourty (2005), state that many times educators impose the creation of work teams in their courses; but without considering minimum guidelines in this regard, for example, how to resolve conflicts, how to reach consensus, how to lead a team, etc.

Teamwork will enhance learning more than individual work, only if instructors plan activities with specific characteristics: learning activities on constructive interdependence among team members, planning of individual achievements related to the objectives as a team, and reflection on the teamwork process (Johnson & Johnson, 1994). Students should then be given feedback and specific spaces for reflection about their team processes; with special emphasis on how to manage work assignment and how to deal with disagreements (Purzer, 2011).

Salas, Sims & Burke (2005), defined teamwork as the set of thoughts, actions, and feelings of each member, which are necessary for the team to work and to facilitate the development of the objectives. An essential characteristic is the trust among the members of the team, the lack of trust affects important processes such as enthusiastic participation and individual contribution. Salas et al. (2005), also warn that the formation of effective work teams is not easy to implement, and that it is not reasonable to expect teamwork to simply happen once the teams are formed.

1.2. Problem statement

A well-known methodology that promotes, among others, teamwork skills, is project-based learning where students receive specifications about a final product that they must achieve, following some suitable procedure (Walker, Leary, Hmelo-Silver & Ertmer, 2015). Project-based learning starts from a specification and assignment of a project, which requires the students to carry out a series of tasks to obtain the final product that can be a model, a design or a prototype. The development and results of the project are usually explained in a written report and / or in an oral presentation (Prince & Felder, 2006). Chiocchio and Essiembre's defined project teams as "groups that perform a defined, specialized task within a definite time period, and whose members are generally cross-functional and disband after project termination" (Chiocchio & Essiembre, 2009, p. 392)

Although many investigations support the instructor-assigned teams (Oakley, Felder, Brent & Elhajj, 2004); in their study Spoelstra, van Rosmalen, & Sloep (2014), detected that, in the usual teaching practice in project-based learning environments, the recommendations of the literature, about team-formation, are little used and that the formation of the team for the project is often left to the self-selection of the students. In addition to its undeniable simplicity for the instructor, self-selection promotes that students can work with colleagues they know and whom they probably understand well (Dutson, Todd, Magleby &

Sorensen, 1997). But, team-forming by Self-selection can affect the quality of work of the team in aspects such as: (a) teams made up only of friends, which hinders the exchange of new ideas; (b) the emergence of teams of high-performance students as opposed to low-performing teams given the tendency of students with similar skills to group, this does not allow lagging students to learn from peers who use better strategies, or that outstanding students develop skills by teaching their colleagues; and (c) the integration problems of underrepresented minority students could remain (Oakley et al., 2004).

What is expressed in the previous paragraph, motivates to study other alternatives, other than self-selection, for the formation of the team. But these alternatives must be relatively easy to implement, and must also be based on conceptual principles, which potentially must promote a good learning environment.

1.3. Purpose of the study

The work of this thesis, of experimental exploratory nature, was about team-effectiveness of engineering students teams assigned by the instructor to have diversity of roles, in a population of end-career undergraduate engineering students, mainly accustomed to team-assignment by self-selection. For this, it was applied the methodology of project-based learning in a course of manufacturing processes aimed at undergraduate third-year students in mechanical/mechatronics engineering. Participating students, in general, had not received, before the course, any specific instruction about teamwork and most of their previous experiences were in teams formed by self-selection. As mentioned, teams' formation was carried out by the instructor, whom applied the UKCES - University of Kent Careers and Employability Service (2004) teamworking skills questionnaire, that allows to identify, among seven roles, the predominant ones that a person can assume in a teamwork situation. The criterion for forming the teams was that each team had the greatest possible diversity of predominant roles as recommended again by UKCES (2004). In the present thesis it was decided to use the UKCES (2004) teamworking skills questionnaire, since it is available online, it is simple to implement, it is a public access resource, and it is inspired by the seminal work of Benne & Sheats (1948) in the literature on team roles, a 1231 times cited source, 21 of them in 2018 (examined in 06-Aug-2018).

1.4. Research question

In a population of end-career undergraduate engineering students, mainly accustomed to team-assignment by self-selection, what can we learn about their team-effectiveness when they work for the first time in teams assigned by the instructor to have diversity of roles?

1.5. Significance of the study

The use of projects and teams of students is a very common practice in engineering education in general and in the Engineering Faculty of the National University of Colombia (FI-UNC) in particular. What is not frequent in the FI-UNC is the use of methodologies informed by literature to promote a structured teamwork experience. The present study is proposed as action research with the purpose of promoting a scholarship of teaching focused on improving the teamwork experience of FI-UNC students.

An important aspect in the planning of student work teams is the assignment of the teams. Two frequent assignment practices are self-selection and random assignment, although them are easy to implement for the instructor, these methods do not promote the diversity of skills in the teams. Other systematic methods of team assignment are not used by instructors, because they represent a significant additional workload. With the present work, I intend to contribute to the exploration of a methodology of assignment of the teams based on roles, which is relatively simple to implement and promotes an intentional diversity of skills within the team.

2. Literature Review

2.1. Methods for team-forming

Probably the most used method for team-forming is self-selection by the students, given its undeniable simplicity for the instructor. This method promotes that students can work with colleagues they know and whom they probably understand well (Dutson et al., 1997). However, several disadvantages of this method have been reported: team members tend to be uncritical of their friends' work; absence of some of the skills required for the project; isolation of students with limited social skills; pressure to join a specific team, and excessive homogeneity of team criteria, which can be detrimental to make adequate engineering decisions (Layton, Loughry, Ohland & Ricco, 2010).

Another simple method of team forming is to assign the members randomly. This procedure does not require explicit planning and it is transparent for students. However, since students' abilities are not taken into account, unbalanced teams may originate (Bacon, Stewart, & Anderson, 2001). Although the random assignment obviously does not present the benefits of the instructor-assigned methods, it can be used for convenience, since it at least mitigates several of the disadvantages of self-selection. Instructors can often use random team-forming in short-term tasks, when there is no real advantage of using a planned instructor-assigned strategy, or when there is not much time to define the teams (Layton et al., 2010).

The most complex alternative is the instructor-assigned methods of team-forming, which allow the instructor to introduce intentional criteria to promote positive team learning experiences (Oakley et al., 2004). However, the instructors rarely use the planned methods to form the teams, because the necessary logistics can be a real challenge. The complexity of team-forming rises considerably with the number of students in the class and with the number of factors to consider. In fact, even the implementation of a few criteria for the formation of the team can be demanding for the instructors, especially if it is included the criterion of availability of the students to coincide and meet in extra-class time, or with large classes that are typical in undergraduate engineering education (Layton et al., 2010).

Fiechtner & Davis (1985, as cited in Oakley et al., 2004) reported that, in a study with 155 students, a third of them stated that their worst team experiences were within self-selection teams and that their best results were with instructor-assigned teams. Koppenhaver and Shrader (2003) concluded that the instructor-assigned teams reach higher stability in the permanence of their members, and that this stability increases the ability of the team to perform well. Additionally, the teams of students instructor-assigned are closer to the usual practice in professional environments, where self-selected teams are rare and generally are used project manager-assigned teams (Hansen, 2006).

Some of the systematic instructor-assigned strategies to group the students, were reviewed by Borges, Dias & Cunha (2009):

> Alternatively, teachers can use grade-based criteria for grouping students, the most common methods being the high with the high and the high with the low schemes (Johnson et al. 1991). Both these methods are simple to put in practice but require the availability of students' previous marks in other courses or in previous examinations of the actual course. (p. 574)
>
> In some studies, the team-formation process is based on the students' stated preferences on a set of previously defined projects (Delson 2001, Wesner et al. 2001). Students indicate their preferences on the proposed projects and teachers form balanced teams based upon student preferences. (p. 574)
>
> Finally, teachers can make use of surveys focused on determining students' specific characteristics in order to form heterogeneous groups (Abrami et al. 1995). Such methods present the advantage of promoting interdependence among students having complementary skills but, may be seen by students as a black box method. Huxland and Land (2000) study a method based on questionnaires for assessing students' learning styles, and Fitzpatrick et al. (2001) present a method in which the Kolbe Conative Index is used to measure students' instinctive behaviour. Finally, Blowers (2003) proposes a method based on student self-assessment that aims at achieving balanced groups, and Pardoe (2006) proposes a method for forming groups whose members have mostly similar schedules without compromising group diversity. (p. 575)

Given the great complexity that a structured instructor-assigned team-forming procedure can achieve, there are several computer-aided team-forming systems, which make it easier for the instructor to collect and process a large amount of student data in the process of assigning a team, according to the criteria that the instructor is interested in applying. As an example of one of these systems, the "Team Maker" system developed by Bacon and his colleagues (Bacon, Stewart, & Anderson, 2001) can be examined.

2.2. Grading of students in teams

Work teams are central to problem and project-based learning. The decision that must be made are if assessing the product, the process or both. Also, is necessary to define if gave a total group grade or an individual one. On this respect, the conclusions of the work of Holgaard & Kolmos (2009), in the context of problem-based projects, suggested that the students and the external experts consider more valuable the group oral exam. Although the individual evaluation is more indicated in the case of projects of narrower scope and where it is desired to verify the individual learning of specific contents. Savin-Baden (2003) proposes the 'tripartite assessment' to individualize the assessment of teamwork:

- Team component (e.g. group report) for which members each receive a mark.
- An individual piece of work that each participant has researched.
- An individual account of the group process that is linked to the theory of group work (e.g. a reflection about their contribution to the group process).

Borrego, Karlin, McNair & Beddoes (2013) suggest, based on their own teaching and research, that part of a specific pedagogical strategy to motivate student participation in the team project, is to use appropriate grading methods. Hellström, Nilsson & Olsson (2009), found in their research that most of

the students considered an exam suitable as a complement to the project, basically because the students considered that in this way a fair individual grade is achieved.

On the other hand, Oakley et al. (2004) assert that "Peer ratings are an effective device for improving team performance, helping students develop teamwork skills, and adjusting team grades for individual performance (Brown, 1995; Harkins & Jackson, 1985; Kaufman, Felder, & Fuller, 2000)" (p. 17). Oakley et al. (2004), also recommend that the criteria for assigning grades must be explicit and that priority must be given to assessing teamwork skills (responsibility and cooperation), rather than assessing individual academic ability (relative contributions). The reason is that when the individual academic capacity is evaluated, competition is fostered and the members of the team that are academically more outstanding are favoured. If the less outstanding students of a team know that their grade will be lower than that of other members, regardless of how much they contribute collectively, they are very likely to feel discouraged.

2.3. Team effectiveness

Team effectiveness is related with the constructs of team processes and its relation with team performance, understood as both the achievement of project goals, and the satisfaction level of team members about their teamwork experience (Werner & Lester, 2001). The literature on team effectiveness in the context of engineering education is extensive, and several authors in this area have proposed models with a large number of constructs (e.g., Sheppard, Dominick & Aronson, 2004). In an approach based on a wide literature review of engineering education, Borrego et al. (2013) decanted the next few constructs in relation to project team's effectiveness, the authors included an explanation of the constructs as well as pedagogical recommendations to deal with them.

> **Social Loafing (avoid)**: The tendency of individuals to exert less effort when working collectively than when working individually. Pedagogical recommendations: compelling project with inherent value; peer evaluation of individual effort; complex tasks; and small teams. (p. 488)
>
> **Interdependence (promote)**: The level of reliance one person, group, or organization has on others in order to complete their work. Pedagogical recommendations: complex projects; group processing; and group grading. (p. 488)
>
> **Conflict (avoid, promote conflict management)**: Perceived incompatibilities or discrepant views among the parties involved in a project or team. Pedagogical recommendations: clear goals and values; discuss conflict as a source of creativity; time and activities for teams to develop consensus; grading that promotes collaboration; class time for team meetings; balance project workload with other student demands; and training on situational awareness for effectively dealing with different levels of conflict. (p. 488)
>
> **Trust (promote)**: Confidence in the ability of others; faith in the trustworthy intentions of others. Pedagogical recommendations: Teambuilding; minimize monitoring behaviours; and grading requirement to know all aspects of project. (p. 488)
>
> **Shared Mental Models (promote)**: Shared knowledge structures that enable a team to form accurate explanations and expectations of the task, to coordinate their actions, and to adapt their

behaviour. Pedagogical recommendations: clarity of project assignment; goal setting together in teams; and group processing. (p. 488)

In a similar approach about team effectiveness Werner & Lester (2001) proposed a framework composed of the next constructs related to the team processes:

Team structure refers to the level at which team members understand and are committed to the team's objectives. The structure also involves that the roles in the team are clearly defined, and that the rules are properly established.

Team spirit includes two concepts, *group potency* and *group drive*. The potency of the group refers to the confidence that a team has in its ability to be effective. The group drive refers to the intensity with which its members invest energy in the interests of the team.

Social support refers to positive interactions and mutual support among team members. High levels of social support should lead to greater overall satisfaction with the experience inside the team and team's performance.

Workload balance refers to the fact that the necessary tasks are well distributed among the members of the team. Such balance should reduce social loafing, manifested in that some team members do not do their fair share of team work.

Communication inside the team. Groups that do not share information effectively may find themselves in situations where the best possible decision fails to be evident over other proposals, because each team member knows only part of the available pertinent information. Teams that communicate agilely, waste less time in meetings and use their resources better, avoiding duplication of work by team members.

2.4. Team dysfunctions

In their research on the performance issues of student teams, Natishan, Schmidt & Mead (2000), found that the most frequent categories of difficulties were interpersonal problems and productivity problems.

A common source of interpersonal problems is the unequal effort (Natishan, Schmidt & Mead, 2000). Oakley et al. (2004) define as hitchhikers those team members who refuse to do their part of the work, and who also try to obtain the same grades as their teammates. According to Hung (2011), "Some group members tend to contribute significantly less than their peers in a variety of ways, such as by missing meetings, being unprepared prior to the meeting, not completing assigned tasks on time (or at all), and not contributing in group discussions and decision-making processes" (p. 542).

Another common source of interpersonal problems are the negative personal attitudes (Natishan, Schmidt & Mead, 2000), for example, it is mentioned that in a mixed group of men and women, the women stopped participating because men systematically ignored their opinions. In this regard, Hung (2011), also mentions attitudes such as, bring personal conflicts to the group, limited communication skills or disinterest to provide support to the other members of the team. Due to lack of social skills, some members of the team may have an aversion to working as a team and are then self-marginalized from participating or try to sabotage the team's effort (Oakley et al., 2004). There are also the team members with dominant personalities who want to force others to follow only their ideas (Oakley et al., 2004). Hung (2011) adds: "Conversely, group members with passive or subservient personalities could contribute little

to the group problem solving and group learning process, which could hinder the attainment of positive learning outcomes (Steinert 2004; Wells et al. 2009)" (p. 542).

Common productivity problems reported (Natishan, Schmidt & Mead, 2000) are scheduling conflicts, irresponsibility with individual commitments, lack of technical skills necessary for some tasks and inadequate planning of team work. On this respect Rebollar et al. (2010) add as another problem when project workloads are distributed unfairly. Another case is team members with non-convergent goals (Oakley et al., 2004), for example, if there are members who are willing to work hard for a good grade, while other colleagues just want to do what is necessary to pass. On this respect Rebollar et al. (2010) also reported that the students in their study complained about different visions of the project by the team members and therefore they did not have a clear idea of the project tasks.

3. Research design

3.1. The course, instructors and students

The participants in this study were 77 engineering students attending a manufacturing processes course during 2018-01 semester. The majority of the students enrolled in the "Manufacturing Processes II" course, are pursuing their third year of undergraduate degree in mechanical engineering or mechatronic engineering at the National University of Colombia in Bogotá. Every semester, up to 80 students are admitted to the subject in four groups of up to 20 students. The course is 3 credits and is divided into a large class theoretical session of 2 hours per week for all the students and a laboratory session of 3 hours per week for each of the four subgroups of average 20 students. Students are expected to work 4 hours per week outside classroom hours.

The laboratory practice is focused on students to learn the fundamentals of computer-assisted manufacturing technologies by applying the design concepts of machining processes that are studied in the large class lectures. The entire course is coordinated by a professor who is in charge of the large class lectures and for the lab sessions there is the participation of an instructor engineer for the topics of computerized numerical control (CNC) and also the participation of two undergraduate teaching assistants trained to be guides in the study of computer-aided manufacturing (CAM) topics.

3.2. Teams formation

Dutson et al. (1997), mention that in the methodology of project-based learning, the team size can be from a single student to all the students in a class. There is a diversity of opinions on the optimal team size. Small teams run the risk of losing a large part of their work force if a student leaves the class. While in large teams there are often "lagged" students who do not contribute to the team's efforts. Todd et al. (1995, as cited by Dutson et al., 1997) asked to several engineering departments, about the team size in the context of project-based learning, the results were: one (9%), 1 to 3 (37%), 4 to 6 (48%), 7 to 9 (4%) and 10+ (2%). Based on the above considerations, a team size of 4 to 5 is used in the present study.

In the present thesis it was decided to use the UKCES (2004) teamworking skills questionnaire, since it is available online, it is simple to implement, it is a public access resource, and it is inspired by the seminal work of Benne & Sheats (1948) in the literature on team roles, a 1231 times cited source, 21 of them in

2018 (examined in 06-Aug-2018). Benne & Sheats (1948), proposed three categories of roles that people can exhibit in small teams: (1) positive roles related to the task, that is, related to achieving the team's work objective; (2) positive roles of team building, that is, related to the construction of good interpersonal relationships for the benefit of the team; and (3) negative egocentric roles, that is, related to attitudes that cause bad interpersonal relationships and make it difficult for the team to reach the objectives.

The selected UKCES (2004) questionnaire of role identification has several similarities with the Belbin's self-perception questionnaire (Belbin, 1996). An important difference between the two is that the UKCES (2004) is simpler, is based on 28 questions and identifies 7 potential roles, while the Belbin's questionnaire is based on 63 questions and identifies 9 potential roles. It should be noted that although Belbin (1996) does not cite the Benne & Sheats (1948) research, it seems to have strongly inspired Belbin's work on teamwork roles.

Teams' formation was instructor-assigned, who applied the UKCES (2004) team-working skills questionnaire, that allows to identify, among seven roles, the predominant ones that a person can assume in a teamwork situation. Examining the roles that result from the UKCES (2004) questionnaire, it is identified that it is inspired by the two groups of positive roles enunciated by Benne and Sheats (1948). The identification of negative roles is not evident in this questionnaire. The criterion for forming the teams was that each team had the greatest possible diversity of identified predominant roles as recommended in UKCES (2004), and as mentioned, the selected teams size was 4 to 5 students.

The UKCES (2004) questionnaire is included in ANNEX A, each role is associated with four statements, which have the answer options: rarely (0 points), sometimes (1 point), frequently (2 points) and always (3 points). In this way the total score for a role can go from 0 points, if the respondent does not have any associated trait, up to 12 points, if the respondent strongly presents the features of this role. A brief description of the associated seven roles as presented in UKCES (2004) is presented below, the detailed description is included in ANNEX E.

- Encourager: He is enthusiastic and raises the mood of the group when motivation is low (team building).
- Compromiser: Is sociable and strives to maintain good relations between all the members of the group (team building).
- Leader: Has the ability to direct the actions of the group toward the common goal (task oriented).
- Summariser/Clarifier: Understands and synthesizes the ideas of the other members to achieve common objectives (task oriented).
- Ideas person: She/he is a generator of ideas to solve problems and organize tasks (task oriented).
- Evaluator: Evaluates the group's proposals with a critical sense, avoiding making hasty decisions (task oriented).
- Recorder: Has the ability to maintain the memory and information flow in the group (task oriented).

3.3. Project specification and assessment

The project is aimed at achieving a part of the intended learning outcomes of the course, related to the planning and execution of manufacturing processes by machining, using computer numerical control (CNC) and computer assisted manufacturing (CAM) technologies. The learning outcomes, enunciated with the support of the SOLO taxonomy of Biggs & Tang (2011) are:

1. Apply, either programming in CNC, or configuring in CAM, the drilling and milling operations of flat and curved surfaces to produce a geometry required in a work piece according to the design requirements.

2. Analyse the geometrical characteristics and the properties of the work material, to choose the appropriate cutting tools for machining operations, and to decide the setup conditions of the process (fixture, coolant, feed rates, cutting speeds, depths of cut, etc.).

3. Reflect about the dynamics of the machine tool, and about the setup of manufacturing operations by machining, to predict the quality and safety results of the manufacturing process.

4. Explain the relationship between workpiece geometric characteristics, the selection of cutting strategies (ramps, helical milling, arcs, etc.), the machine setup, and the global results of machining operations.

About the team-project specification, Hansen (2006) suggests using large, full-semester projects of high relevance to the subject of study. Additionally, this author considers as fundamental a very well-established parameters and a clear expected result of the team project. On the other hand, Kirschner, Paas & Kirschner (2009) concluded that the learning tasks assigned to the teams (problems, projects, etc.) must be complex in nature and, therefore, should not be easily carried out by a single student. In the present study, a group size not too large, not too small, of 4 to 5 students was chosen. Consequently, the complexity of the project was also conceived so that 4 to 5 members had enough work. Taking into account the above considerations, the manufacturing project proposed to the work teams consisted of three stages:

1. From a real engineering system, the team must propose a complex component to be manufactured by using the computer numerical control (CNC) and computer-aided manufacturing (CAM) technologies covered in the course.

2. By using the CAM system available in the manufacturing laboratory, teams must design the entire manufacturing process of the proposed component. This step involves using a large part of the content of the course, specifically: selection of cutting tools, determination of basic process parameters, calculation of operating parameters, definition of sequences of operations, determination of convenient machining strategies and process safety analysis.

3. Finally, using virtual models of numerical control (CNC) machine tools available in the laboratory and implemented in the CAM system, the teams must perform the modelling and simulation of the setup and the complete manufacturing machining process of the selected component.

With the previous formulation, the intentional problems that the teams will have to face to complete the project are clear. However, it is very likely that unintentional technical problems arise that are also part of the intended learning.

The project was assessed by using a rubric for the technical report of the project (see ANNEX C), designed by following the recommendations of Masmitjà et al. (2013), and a rubric for the final presentation of the project (see ANNEX D), developed on our own experience with prior students' presentations. The reason to use rubrics was to promote a fair assessment. The students knew the assessment rubrics in advance so that the teams worked in concrete elements for their improvement.

Following the recommendations of Hellström, Nilsson & Olsson (2009) and Oakley et al. (2004), commented in "Grading of students in teams" section, at the end of the semester, each student received a cumulative grade of the project. In order to obtain an individual grade, were performed: an individual final CNC and CAM test (30%), project and presentation assessment (50%), and average self-evaluation plus peer evaluation (20%) in a questionnaire-based survey (ANNEX B).

3.4. Instruction about teamwork

In the first session the work teams were assigned by the instructor according to the methodology presented in the previous section. Also, to motivate the interaction between the newly assigned teams, the activity known as the "marshmallow challenge" (Skillman, 2006; Wujec, 2010) was carried out. The activity consists in constructing in 18 minutes a structure with 20 sticks of spaghetti + one yard tape + one yard string + one marshmallow in which, the marshmallow should reach the highest possible height. The winning team is the one whose marshmallow registers the highest height in a self-supporting structure not stuck to the support surface.

This was the first interaction between several of team members and it served to motivate the socialization among them. It was also an opportunity to reflect on the successes and mistakes in the mini project of the "marshmallow challenge" and on teamwork in general.

After this activity, were presented the following rules, adapted from Oakley et al. (2004), each work team must:

- Establish the communication and meeting mechanisms that they prefer (face to face and / or virtual).
- Agree on a weekly schedule to meet and previously establish the tasks that each team member must perform to present at the meeting
- If there is a problem that cannot be solved by team members. It is recommended to seek the mediation of the instructor.
- If one or several members of the team systematically refuse to cooperate in the development of the project, the other members must formalize in writing their exclusion from the team. Copy of the notification email should also be sent to the instructor.
- It is also permissible to withdraw from a team voluntarily, students who withdraw from the team or remove them from the team must negotiate their inclusion in another team.

3.5. Research approach

For this study, the author selected an exploration with a qualitative method, given the small sample and that it was intended to extract information with only one run of the manufacturing processes course by forming the project teams with the proposed instructor-assigned grouping method. According to Borrego (2009):

> In comparison to quantitative studies, with their emphasis on large, representative samples, qualitative research focuses on smaller groups to examine a particular context in great detail. The goal is not to provide a broad, generalizable description that is representative of most situations, but rather to describe a particular situation in enough depth that the full meaning of what occurs is made apparent. This approach is particularly useful when considering unusual or non-traditional cases. (p. 57)

The selected research approach can be classified also as an exploratory design (Creswell et al., 2003) and as an action research (Feldman & Minstrell, 2000), because based on the qualitative information obtained, the author can create quantitative instruments in the future, and the qualitative data also serves to improve problematic aspects of the teamwork of the students of the course in future versions. This thesis is a thematic analysis on what is only the first phase of an action research project and the author intend to pursue the project further.

3.6. Research method

Remembering our research question: in a population of end-career undergraduate engineering students, mainly accustomed to team-assignment by self-selection, what can we learn about their team-effectiveness when they work for the first time in teams assigned by the instructor to have diversity of roles?

Team effectiveness was researched through Students' written comments and opinions. This data was obtained through the information gathered in their team's process analysis reports and in an individual teamwork evaluation survey (see ANNEX B). Here it is important to remark that the students were asked to grade themselves, their team and their colleagues, but only as part of our team instruction. We used only their comments for our inquiry.

Qualitative data was analysed within the framework proposed by Marshall & Rossman (1989) that includes organize the data; generate categories, themes, and patterns; test the emergent hypotheses against the data and search for alternative explanations for the data.

The process analysis data and the individual questionnaire data were merged for the analysis. Data approaching was semantically, i.e. students' comments were treated as objectively meaning what was written. The approach to the phenomenon under study was of dynamic nature, due that the researcher is interested in the process, things that can be changed. In order to determine patterns, themes or categories through which the researcher was able to analyse the data, the approach was theory driven (deductive), based on the theory constructs about team-effectiveness presented in the literature review.

3.7. Instruments

Questionnaire-based survey: The "*Peer rating of team members*" questionnaire proposed by Oakley et al. (2004) was adapted to obtain, confidentially and on behalf of each individual student, an assessment of teamwork, a self-assessment and a peer assessment of the work of each one of their colleagues. For each of the three mentioned parts, the students assigned a grade (1 to 5) and commented on the team's work, on their own participation and on the participation of each one of the other members. The questionnaire was implemented online as a Google form to be completed online (see ANNEX B). Only the students' comments are of interest for this research. Their peer-assessment grades were used as a part of the assessment of their individual project work.

Team process analysis: Along with the report and the technical material of the project, the students were asked to submit a process analysis including: reflections on the management of the project, reflections on the individual and group learning processes, as well as recommendations for their future work in teams. The idea is to contrast the process analysis of the team with the individual responses of each member in the confidential questionnaire mentioned in the previous paragraph.

3.8. Project activities and data collection

The "Manufacturing processes II" course was developed during 16 weeks. In the 2 hours of large-class per week with all 76 students, the theoretical topics related to the design of machining processes were worked on. To follow, are reviewed the activities of the course related to the project, which were developed essentially in the machine-tools laboratory, during the sessions of 3 hours per week, for each one of the 4 subgroups of up to 20 students.

- Week 1: Teams were assigned by the instructor following the methodology already presented. In total, 16 teams of between 4 to 5 members were formed. It was done the instruction about teamwork, including the "marshmallow challenge".
- Week 2: The project specification and the project assessing rubric were presented to the students. Starting of CNC and CAM classes.
- Week 3: About their projects, the teams presented their proposals of complex components taken from a real engineering system. Continuing of CNC and CAM classes.
- Week 4 to week 9: Teams had the opportunity to resolve doubts about the progress of their projects with the teaching assistants and with the technical engineer of the laboratory. Continuing of CNC and CAM classes.
- Week 10: Teams made a progress presentation of their projects.
- Week 11: Teams had the opportunity to resolve doubts about the progress of their projects with the teaching assistants and with the technical engineer of the laboratory. Completion of CNC and CAM classes.
- Week 12 to week 14: Teams had the opportunity to resolve doubts about the progress of their projects with the teaching assistants and with the technical engineer of the laboratory.

- Week 15: Teams submitted their project reports, including the process analysis. Students completed the confidential assessment survey about teamwork. To assess the technical report of the project, the project assessing rubric was used.
- Week 16: Teams made the final presentation of their projects, to assign the presentation grades, it was used the rubric of presentations assessment. This rubric was explained to the students one week before the presentation.

4. Findings and discussion

The theory on team-effectiveness presented in the "Literature review" section was the framework to search for the more frequent themes on the data. Those salient themes were: interdependence and team structure, shared mental models, communication inside the team, conflict management, social loafing and scheduling conflicts.

4.1. Interdependence and team structure

In collaborative learning environments, Johnson, Johnson & Smith (1991) state that there are four kinds of interdependence for effective learning: (1) goals interdependence; (2) rewards interdependence; (3) role interdependence; and (4) resources interdependence. In this regard Johnson & Johnson (1994) suggests that the instructor can assign roles in the team to foster interdependence. In the present study the roles were input for teams-assignment, but the students were free to organize themselves internally as they preferred.

Some teams exhibited comments that suggest role interdependence. A team highlighted the method of team-assignment by the instructor as a situation close to a real professional situation, in which one must work with strangers, without knowing their skills and abilities. Another team mentioned that they obtained experience in situations that are not usually the subject of their courses, among them the organization of work teams based on complementary skills. In another team its members declared that they assumed the roles that were identified for team-assignment: a leader, an ideas person, an evaluator and a recorder. On this respect, a student of another team reported that the roles determined for team assignment were also very useful to organize the team. Another team used a strategy of task-assigning not to individual members but to subgroups, within which they report that defined roles emerged: an executor role and a guiding-checker role. Colbeck, Campbell & Bjorklund (2000), found that a similar strategy was used by a group of students at the University of Washington to reduce opportunities for social loafing, in this case, groups of more than four or five were subdivided into groups of two to four members. According to Hernandez (2002), collaborative learning is one of the benefits associated with team projects. In this regard, in two of the teams, the most expert members in some topics, affirmed that they assumed the role of instructors of their colleagues with less knowledge.

Resource interdependence is present when a team establishes that each member has a skill to complete the project, and all the members are necessary to complete it (Johnson, Johnson & Smith, 1991). In nine team reports, it was declared a process of identification of skills and/or strengths and/or weaknesses and/or aptitudes and/or capabilities. Then, based on the information from the previous step, these teams generally affirmed that they proceeded to assign to each member the roles and/or tasks appropriate to

his/her profile. Although these teams did not mention any of the roles used to team-assignment, it is interesting that they used skill roles within their strategy to organize the work.

About team leadership, in three of the teams, the leader role was assumed manifestly by one of the students. In another case, the students affirmed that the leader role was not exclusive of any member, and that it emerged spontaneously depending on the objective of the team at that time. Similarly, another team stated that they avoided the dominance of any of the members in particular. In this regard, Johnson & Johnson (1994), suggested that shared leadership is a positive team characteristic. Some related quotes were:

"During this phase it was possible to notice the interest and good participation on the part of all the members, as well as the abilities and roles that each one had, such as the leader person, the one of the ideas, who verifies, who doubted and asked, always respecting the other members and being willing to listen to any opinion. So, we divided these tasks among the members of the team, taking into account that the progress of each of the members depended on the other."

"For the management of this project, the team first of all emphasized to distinguish the capacities and abilities of each one of the members with the purpose of distributing the tasks in the most optimal way possible, looking for with this the development of each one of these tasks in the best way. This also sought to develop a learning environment where those members within the team that had greater skills in specific tasks, could instruct those who were still in the process of learning the selection of tools, operations and software usage."

"The effectiveness of a team is based on its diversity. This is why it is very important that from the first meetings we talk about the strengths and weaknesses that each person has for the realization of the project, defining the roles that each one can occupy."

4.2. Shared mental models

Several of the students' comments evidence the existence or gradual emergence of shared mental models. A group of students reported that the team was built gradually, starting with the identification of common objectives. In this regard, Stevens and Campion (1994) stated that the ability of teams to establish team goals that are specific and challenging is one of the characteristics required for successful teamwork. This is also an indication of the construction of goal interdependence (Johnson et al., 1991). On the other hand, a student mentioned the importance to understand the other members perspective. While another student affirmed that it is indispensable to adapt the personal work strategies to teamwork strategies. Additionally, another student remarked that the students use the same language to explain and this is more effective than learning from the instructors. This last comment points to one of the principles on which the success of peer-instruction (Mazur, 1999) is based: the homogeneity of language and mental models among students. Some related quotes were:

"The idea of promoting learning not only with the teacher-student relationship, but also with the relationship between the students is very good and very useful, knowing that among us we use the same language and use different tools to explain."

"Be open to the opinions of the other members, because a view from different perspectives can generate better learning processes and a better development of the project."

4.3. Communication inside the team

Teams that communicate agilely, waste less time in meetings and use their resources better, avoiding duplication of work by team members (Werner & Lester, 2001). Many comments from the students and the teams were about different aspects of the communication between team members. One of the main reasons was the fact that many students were working together for the first time and several of them did not know each other personally before the course. This evidence suggests that the development of communication skills was promoted due to the need to work with new colleagues. As example, a student mentioned that by "forcing" them to work as a team they had to find a way to communicate well.

Several students felt that a good communication with other professionals is a valued ability for their future career development. Some teams informed that from the beginning of the project they managed a good communication through a group of instant messaging. Other students related that communication was difficult at the beginning, but improved with time. In this regard, some students recommended reinforcing the teamwork activity carried out at the beginning of the course, while other commented the need to conduct socialization activities among the newly-presented members of the teams. Class attendance was mentioned several times as the most feasible way to meet with the other team members. All these observations suggest the need to introduce more specific activities of teamwork training and socializing between new team members. Also, it seems advisable to give a specific time in class for the teams to meet. Some related quotes were:

"Generate clear communication among all team members, where everyone understands their responsibilities and has a complete understanding of what is required to be done, both as a group and personally."

"It is important to share the work that is being done, so you can make revisions, corrections and improvements, since it is normal to divide the work, and as expected at the time of putting everything together, sometimes certain elements don't match, therefore, there must be face-to-face meetings to review the work as a whole."

"As a recommendation to the class, it would be very helpful to emphasize the team's work and communication between colleagues, reinforcing the activity or workshop at the beginning of the semester. It is usual that engineering students are not familiar with teamwork and find it difficult to get used to the personalities and abilities of new colleagues."

"Work teams should be created well to avoid communication problems."

4.4. Conflict Management

A recurring theme that emerged in the student comments was the need to address the conflict between team members. In this regard Purzer (2011) recommends that teams should either be monitored closely or taught self-monitoring and conflict management skills. There were several comments about the inconvenience of working with strangers, as this increases the team problems. On the other hand, several students considered that is normal that problems arise when working with new people, but they managed to overcome the conflict situations. On this respect a team emphasized the importance of conflict management skills for their future professional performance. A team mentioned that they had the need

to reprogram some member tasks, but with a greater commitment to the new deadlines. Two of the teams mentioned the possibility of another colleague assuming or supporting the missing work. This behaviour is also a construct of team effectiveness called "Backup Behaviour" in the model of team effectiveness proposed by Salas et al. (2005). Some students, assuming a typical compromiser role (UKCES, 2004), pointed to the need to maintain good relations between the members, but making sure to remember that each member has a responsibility. Some related quotes were:

"It is vital to be honest with the work team, if for some reason you cannot attend an agreed meeting or if you are late with the assigned work; You can avoid conflicts by speaking clearly about why, propose a solution and make a commitment to the group. It is also possible that someone from the group can help those who are behind in their work. It is to understand that sometimes for X or Y reason our work does not go as we expect or there is an inconvenience and among all, it is possible that it is solved quickly."

"Working as a team is always a challenge, even more so with people with whom we had not had prior contact, however, we managed to understand each other; It is important to work being aware of our individual skills, assigning roles and without seeking prominence, we must work for the good of the team, even when that implies removing from the team the people whose collaboration was null."

"Teamwork was efficient, there were some problems, as expected. However, through the contribution of ideas and discussions on the corresponding topic by the members, it was possible to obtain a satisfactory result."

4.5. Social loafing

Within the comments also emerged the common problem of unequal effort, with hitchhiker members who refuse to do their part of the work. Colbeck, Campbell & Bjorklund (2000) found that students generally avoid teaming with renowned hitchhikers. But the students in this course could not choose their teammates, and some of them had to deal with slackers. Five students reported that a few members did almost all the work alongside the lack of interest and the lack of commitment shown by the other teammates. This is a typical case of social loafing in which the role of slacker or hitchhiker is generated in the team. Only in one team, the working members decided to expulsed one slacker, while in another four teams, with presence of slackers, the working members preferred to maintain them, apparently to avoid the conflict. Some related quotes were:

"Teamwork has not been easy, especially due to the concentration of work in a few individuals, along with the lack of interest and lack of commitment shown by others. As general recommendations for other teams, it is important to define a work plan from the beginning. This would have avoided an inconvenient work distribution and would have given clarity of dates and responsibilities to each member of the team."

"Sometimes the bad attitude and the lack of responsibility prevent us from achieving simple objectives that compromise the general objective of the team. If individually we are not able to answer for our own workspaces, we should reflect on how we can be affecting our groupmates. If there is no passion and commitment from the beginning, we cannot expect the best results, just a result."

4.6. Scheduling conflicts

Scheduling conflicts and inadequate planning of team work are common productivity problems (Natishan, Schmidt & Mead, 2000). A team reported that they had problems because they did not prepare a timetable for the whole project or for each of its stages. Another team suffered because there were recurrent delays in internal deliveries. Some teams mentioned that, due to the lack of adequate work planning, they ended up doing many activities at the last minute, without having the necessary time to make revisions and corrections. Other students reported that in their timeline they underestimated the complexity, and consequently the execution times needed for some activities. Another student referred to the fact that their meetings were not productive for lack of a work agenda, and two more students mentioned that their teams did not organize the sufficient number of meetings to coordinate the work. Some related quotes were:

"One of the important activities that must be carried out when forming a work team for a project or task, which was missing in some phases of the project, was to establish a schedule with the activities that will be carried out during all the development of the project or during the phases that compose it."

"The schedule and fulfilment of due dates proposed internally is of high relevance in the work team, this provides security, trust and commitment in each member. Therefore, it is highly recommended to make a schedule of activities and group deliveries that are stipulated in order to achieve significant progress in the project, and thus meet the due dates, because sometimes it can be presented that the complexity and time necessary to develop some work is underestimated."

4.7. Reliability and validity

The study involved direct interaction of the researcher, as instructor and coordinator of the course, with the participating students during 16 weeks. The research plan used could be used in other contexts. The purpose and use of each of the instruments used was explained to the participants before their implementation. The instruments used in this project (survey to form the teams, process analysis reports, and evaluation survey on the internet) were all applied in Spanish language, which is the native language of the participants, thus avoiding problems of interpretation. However, it should be noted that the reliability and validity of the instruments used is not known.

5. Conclusion

5.1. Examination of research question

In a population of end-career undergraduate engineering students, mainly accustomed to team-assignment by self-selection, what can we learn about their team-effectiveness when they work for the first time in teams assigned by the instructor to have diversity of roles?

The salient themes found were: interdependence and team structure, shared mental models, communication inside the team, conflict management, social loafing and scheduling conflicts. The constructs of team spirit and social support were no detected, this is possibly due to the fact that these

characteristics develop over time, and in this case most of the students were working together for the first time.

Interdependence and team structure:

Role interdependence as well as resource interdependence was apparently developed inside several teams, who used identification of skills with the purpose of assign to each member the roles or tasks appropriate to his/her profile, developing resource interdependence inside the team. Other teams declared the used of specific roles, not associated with technical skills, evidencing role interdependence. In all these teams, the role concept that was introduced within the team assignment method probably motivated its members to designate specific roles, not necessarily the same as those detected in the assignment of the teams. The leadership role was also evident in some teams, and even cases of shared leadership were detected.

Shared mental models:

The existence or gradual emergence of shared mental models was evidenced in several students' comments, also it was detected goal interdependence. There were opinions like: starting with the identification of common objectives; the importance to understand the other members perspective; the adaptation of the personal work strategies to teamwork strategies; and the existence of a shared language between student peers.

Communication inside the team:

Communication inside the team was a recurring difficulty. The main cause of communication problems was that many of the students were working together for the first time, due to the team assignment method. This finding suggests that in the teams formed by the instructor, the development of communication skills is promoted due to the need to work with new colleagues. Class attendance and tools of instant messaging were referred as possible strategies to achieve the adequate level of communication inside the team. Some of the participants did not find it a good experience to work with colleagues they did not know before. Because the students participating in this study are used to the teams assigned by self-selection, this time they had to make a greater effort of communicative skills to advance their projects. Another issue that emerged in the reports of several teams and in several individual comments was the need to reinforce the specific training in team skills, and in this study in particular, there were suggestions to carry out socialization activities among the team members developing a project for the first time. It seems advisable to give a specific time in class for the teams to meet.

Conflict management:

A risk that increases in cases of teaming with new colleagues is the generation of conflicts. However, this is also a learning opportunity for students in conflict management skills. Several students suggested mechanisms and attitudes for conflict resolution. Several students considered also that is normal that problems arise when working with new people. If there are members with the compromiser role in the teams, it may improve the management of the conflict.

Social loafing

In some teams the undesirable role of slacker or hitchhiker was presented in the team. In the teams assigned by self-selection, the students avoid this type of members, but in the present study, with teams assigned by the instructor the students faced this problem. Although in the initial instructions it was suggested to the students not to allow the continuity of the slackers in their teams, only one team reported an expulsion. In other teams, students apparently preferred to avoid personal conflict by keeping the slackers in the project.

Scheduling conflicts:

Several teams suffered the common problems of scheduling conflicts and inadequate planning of team work. Detected issues included: the lack of a timetable for the project; recurrent delays in internal deliveries; doing many activities at the last minute; underestimation of task complexity; lack of a work agenda for the team meetings; and insufficient work meetings.

5.2. Implications for teaching

The possibility of team-assignment assuring the existence of diverse and complementary roles in the team is one of the possible methods that the instructors can use. In addition to the general advantages mentioned for the instructor-assigned teams in the "Methods for team-forming" section, an additional potential advantage with the role diversity assignment is that, with diverse team skills, the team's dynamics will possibly provide more learning opportunities for students in communication skills, conflict management, and role assignments for managing projects. However, as widely reported in the literature (i.e Purzer, 2011), it is also essential to instruct students and give them periodic feedback about their teamwork process. The results of this study suggest also specific instruction in scheduling tools and about conflict management with emphasis in recommended team actions when social loafing occurs.

5.3. Limitations of the study

The previous experiences of the students in teamwork were generalized according to the frequent practices in the Engineering Faculty of National University of Colombia, however, it is possible that the students have other types of teamwork experiences that were not considered and influence the results of the study.

The students provided information about their teamwork in their group reports, while in their individual questionnaires they provided additional information about teamwork, in addition to evaluating their team, themselves and their colleagues. It is important to mention that in the academic culture of the Faculty of Engineering of the National University of Colombia, these modalities of reflection and evaluation are not usual.

The present study is of limited scope, due that only the data about one course and during a single academic period was analysed. A more complete study should include more courses and several academic periods, as well as the perspective of the instructors. The kind reader is then warned that the conclusions are not generalizable, and that they only have applicability in the context in which the study was conducted.

5.4. Possible further work

The students' opinions were collected through open questions. In a later study, an instrument could be designed to detect the role actually performed by the student in his team, and establish whether there is connection with the detected role for the assignment of the team. Also, spontaneous team roles can be investigated in more complex tasks where it is not easy to achieve an acceptable result if all the members do not work.

The preferred roles in the team could also be examined and updated with more specific research such as the one conducted by Purzer (2011), in which it was determined, based on the verbal interaction among the students, which are the preferred characteristics of their discourse in relation to their participation in the team.

References

Bacon, D. R., Stewart, K. A., & Anderson, E. S. (2001). Methods of assigning players to teams: A review and novel approach. *Simulation & Gaming, 32*(1), 6-17.

Belbin, R. M. (1996). *How Management Teams Work*. Butterworth-Heinemann, Oxford.

Benne, K. D., & Sheats, P. (1948). Functional roles of group members. *Journal of social issues, 4*(2), 41-49.

Biggs, J. B., & Tang, C. (2011). *Teaching for quality learning at university: what the student does* (4. ed). Maidenhead: McGraw-Hill, Society for Research into Higher Education & Open University Press.

Borges, J., Dias, T. G., & Cunha, J. F. E. (2009). A new group-formation method for student projects. *European Journal of Engineering Education, 34*(6), 573-585.

Borrego, M., Douglas, E. P., & Amelink, C. T. (2009). Quantitative, qualitative, and mixed research methods in engineering education. *Journal of Engineering Education, 98*(1), 53-66.

Borrego, M., Karlin, J., McNair, L. D., & Beddoes, K. (2013). Team effectiveness theory from industrial and organizational psychology applied to engineering student project teams: A research review. *Journal of Engineering Education, 102*(4), 472-512.

Chiocchio, F., & Essiembre, H. (2009). Cohesion and performance: A meta-analytic review of disparities between project teams, production teams, and service teams. *Small Group Research, 40*(4), 382–420.

Colbeck, C. L., Campbell, S. E., & Bjorklund, S. A. (2000). Grouping in the dark: What college students learn from group projects. *The Journal of Higher Education, 71*(1), 60-83.

Creswell, J. W., Plano Clark, V. L., Gutmann, M. L., & Hanson, W. E. (2003). Advanced mixed methods research designs. *Handbook of mixed methods in social and behavioral research, 209*, 240.

Dutson, A. J., Todd, R. H., Magleby, S. P., & Sorensen, C. D. (1997). A review of literature on teaching engineering design through project-oriented capstone courses. *Journal of Engineering Education, 86*(1), 17-28.

Feldman, A., & Minstrell, J. (2000). Action research as a research methodology for the study of the teaching and learning of science. *Handbook of research design in mathematics and science education*, 429-455.

Hansen, R. S. (2006). Benefits and problems with student teams: Suggestions for improving team projects. *Journal of Education for business, 82*(1), 11-19.

Hellström, D., Nilsson, F., & Olsson, A. (2009). Group assessment challenges in project-based learning–Perceptions from students in higher engineering courses. In 2: *a Utvecklingskonferensen för Sveriges ingenjörsutbildningar, 2009*.

Hernandez, S. (2002). Team learning in a marketing principles course: Cooperative structures that facilitate active learning and higher level thinking. *Journal of Marketing Education, 24*, 73–85.

Holgaard, J. E., & Kolmos, A. (2009). Group or individual assessment in engineering. *Science and health. Research on PBL Practice in Engineering Education*, 57-69.

Hung, W. (2011). Theory to reality: A few issues in implementing problem-based learning. *Educational Technology Research and Development, 59*(4), 529-552.

Johnson, D. W., & Johnson, R. T. (1994). *Learning together and alone: Cooperative, competitive and individualistic learning*. Boston: Allyn & Bacon.

Johnson, D. W., Johnson, R. T., & Smith, K. A. (1991). *Cooperative learning: Increasing college faculty instructional productivity* (ASHE-ERIC Higher Education Report No.4). Washington DC: The George Washington University, School of Education and Human Development.

Kirschner, F., Paas, F., & Kirschner, P. A. (2009). A cognitive load approach to collaborative learning: United brains for complex tasks. *Educational Psychology Review, 21*(1), 31-42.

Koppenhaver, G. D., & Shrader, C. B. (2003). Structuring the classroom for performance: Cooperative learning with instructor-assigned teams. *Decision Sciences Journal of Innovative Education, 1*, 1–21.

Layton, R. A., Loughry, M. L., Ohland, M. W., & Ricco, G. D. (2010). Design and validation of a web-based system for assigning members to teams using instructor-specified criteria. *Advances in Engineering Education, 2*(1), 1–28.

Marshall, C., & Rossman, G. B. (1989). *Designing qualitative research*. Newbury Park, CA: Sage.

Masmitjà, J. A., Irurita, A. A., Trenchs, M. A., Miró, M. B., Marín, A. C., Busquets, M. C., ... & Ruiz, L. M. (2013). Rúbricas para la evaluación de competencias. *Cuadernos de docencia universitaria, 26*.

Mazur, E. (1999). *Peer instruction: A user's manual*. Prentice Hall

Natishan, M. E., Schmidt, L. C., & Mead, P. (2000). Student focus group results on student team performance issues. *Journal of Engineering Education, 89*(3), 269-272.

Oakley, B., Felder, R. M., Brent, R., & Elhajj, I. (2004). Turning student groups into effective teams. *Journal of student centered learning, 2*(1), 9-34.

Patil, A., & Codner, G. (2007). Accreditation of engineering education: Review, observations and proposal for global accreditation. *European Journal of Engineering Education, 32*(6), 639-651.

Prince, M. J., & Felder, R. M. (2006). Inductive teaching and learning methods: Definitions, comparisons, and research bases. *Journal of engineering education, 95*(2), 123-138.

Purzer, Ş. (2011). The relationship between team discourse, self-efficacy, and individual achievement: A sequential mixed-methods study. *Journal of Engineering Education, 100*(4), 655-679.

Rebollar, R., Lidón, I., Cano, J. L., Gimeno, F., & Qvist, P. (2010). A tool for preventing teamwork failure: The TFP questionnaire. *International Journal of Engineering Education, 26*(4), 784.

Salas, E., Sims, D. E., & Burke, C. S. (2005). Is there a “big five” in teamwork?. *Small group research, 36*(5), 555-599.

Savin-Baden, M. (2003). *Facilitating problem-based learning*. McGraw-Hill Education (UK).

Sheppard, K., Dominick, P., & Aronson, Z. (2004). Preparing engineering students for the new business paradigm of international teamwork and global orientation. *International Journal of Engineering Education, 20*(3), 475-483.

Shuman, L. J., Besterfield-Sacre, M., & McGourty, J. (2005). The ABET “professional skills”—Can they be taught? Can they be assessed?. *Journal of engineering education, 94*(1), 41-55.

Skillman, P. (2006). *The Design Challenge - TED Talk*. Retrieved from https://www.youtube.com/watch?v=H0_yKBitO8M on 01-Jan-2018

Spoelstra, H., van Rosmalen, P., & Sloep, P. (2014). Toward Project-based Learning and Team Formation in Open Learning Environments. *Journal of Universal Computer Science, 20*(1), 57-76.

Stevens, M. J., & Campion, M. A. (1994). The knowledge, skill, and ability requirements for teamwork: Implications for human resource management. *Journal of Management, 20*, 503–530.

UKCES - University of Kent Careers and Employability Service (2004). *Teamworking Skills*. Retrieved from https://www.kent.ac.uk/careers/sk/teamwork.htm on 01-Jan-2018

Walker, A. E., Leary, H., Hmelo-Silver, C. E., & Ertmer, P. A. (Eds.). (2015). *Essential readings in problem-based learning*. Purdue University Press.

Werner, J. M., & Lester, S. W. (2001). Applying a team effectiveness framework to the performance of student case teams. *Human Resource Development Quarterly, 12*(4), 385-402.

Wujec, T. (2010). *Build a tower, build a team - TED Talk*. Retrieved from https://www.youtube.com/watch?v=H0_yKBitO8M on 01-Jan-2018

ANNEX A - UKCES (2004) Questionnaire - The roles you play in teams

- The questionnaire which follows should help you to analyse the workings of a group and should help you to reach some tentative conclusions about your role in a team.
- Try to answer the 28 questions as honestly as you can.
- If you select rarely write 0, sometimes write 1, frequently write 2 and for always write 3

		Rarely	Sometimes	Frequently	Always
A	I am an optimist who tends to look on the positive side				
	I support and praise other team members				
	I use humor to remove stress on teams in which I work				
	I try hard to keep up my team's energy level				
B	I help others to find compromises between differing viewpoints				
	I am willing to compromise my own view to obtain consensus				
	I try to keep relations between team members harmonious				
	I make sure all possibilities are explored				
C	I listen carefully to what other team members have to say and try to get quiet team members to contribute				
	I ask others to take responsibility for particular tasks				
	I usually lead and coordinate team efforts				
	I am more concerned with major issues than with details				
D	I elaborate on what others have said				
	I clarify other people's contributions				
	I summarize what has been said				
	I think through proposed plans all the way to the end				
E	I introduce new ideas to teams in which I work				
	I build on the ideas of others				
	I suggest new ways of doing things				
	I suggest new ways of looking at problems				
F	I am not swayed by emotional arguments				
	I use dispassionate, critical analysis to make decisions				
	I am good at evaluating competing proposals				
	I stick up for my opinions and try to argue persuasively and with logic for them				
G	I act as the note-taker for team meetings I am involved in				
	I am a well-organized individual who is good at keeping to deadlines				
	I don't allow the team to over-run the time limit for the task				
	I act as the spokesperson to deliver the findings of the team				

Now add the score for each category

A Encourager	B Compromiser	C Leader	D Summarizer/ Clarifier	E Idea Person	F Evaluator	G Recorder

ENCOURAGER

Energises groups when motivation is low through humour or through being enthusiastic.

They may say:

"We CAN do this!"

"That's a great idea!"

COMPROMISER

Tries to maintain harmony among the team members.

They may say:

"We haven't heard from Mike yet: I'd like to hear what you think about this."

"I'm not sure I agree. What are your reasons for saying that?"

LEADER

Good leaders direct the sequence of steps the group takes and keep the group "on-track".

They may say:

"Let's come back to this later if we have time."

"We need to move on to the next step."

"Sue, what do you think about this idea?"

SUMMARISER/CLARIFIER

Calm, reflective individuals who summarise the group's discussion and conclusions. They clarify group objectives and elaborate on the ideas of others.

They may say:

"So here's what we've decided so far"

"I think you're right, but we could also add ...."

IDEAS PERSON

The ideas person suggests new ideas to solve group problems or suggests new ways for the group to organize the task.

They may say:

"Why don't we consider doing it this way?"

EVALUATOR

Evaluators help the group to avoid coming to agreement too quickly.

They may say:

"What other possibilities are there?"

or "Let's try to look at this another way."

or "I'm not sure we're on the right track."

RECORDER

The recorder keeps the group focused and organised. They make sure that everyone is helping with the project.

They may say:

"We only have five minutes left, so we need to come to agreement now!"

"Do we all understand this chart?"

"Are we all in agreement on this?"

ANNEX B - Questionnaire-based survey - Peer rating of team members

TEAMWORK EVALUATION PMII-LAB

- WHAT TEAM DOES YOU BELONG TO? _____
- WHAT'S YOUR NAME? _____

ASSESSING TEAMWORK

- HOW WOULD YOU RATE YOUR WORK TEAM? > POOR 1 2 3 4 5 EXCELLENT

YOUR CONTRIBUTIONS TO THE TEAM

- HOW WOULD YOU RATE YOUR PARTICIPATION AND COLLABORATION? > POOR 1 2 3 4 5 EXCELLENT
- DESCRIBE YOUR PARTICIPATION AND CONTRIBUTIONS _____

ASSESSING TEAM MEMBERS

TEAM MEMBER 1

- MEMBER RATING 1 > POOR 1 2 3 4 5 EXCELLENT
- COMMENTS ON MEMBER 1 _____

TEAM MEMBER 2

- MEMBER RATING 2 > POOR 1 2 3 4 5 EXCELLENT
- COMMENTS ON MEMBER 2 _____

TEAM MEMBER 3

- MEMBER RATING 3 > POOR 1 2 3 4 5 EXCELLENT
- COMMENTS ON MEMBER 3 _____

TEAM MEMBER 4

- MEMBER RATING 4 > POOR 1 2 3 4 5 EXCELLENT
- COMMENTS ON MEMBER 4 _____

ADDITIONAL COMMENTS

- DO YOU HAVE ANY ADDITIONAL COMMENTS? _____

ANNEX C - Rubric for project assessment

Grading of the project

1. From a real engineering system, the team must propose a complex component to be manufactured by using the computer numerical control (CNC) and computer-aided manufacturing (CAM) technologies covered in the course.

ADVANCED (4.6-5.0): The component was taken from a real engineering system, it is complex and for its manufacture is required to design several CNC operations, manually and in the CAM system.

INTERMEDIATE (3.6-4.5): The component was taken from a real engineering system, but it is not too complex. For its manufacture is required to design some CNC operations, manually and in the CAM system.

BASIC (2.1-3.5): The component was taken from a real engineering system, but it is so simple. For its manufacture is required to design manually some CNC operations. The use of the CAM system is not strictly necessary.

INSUFFICIENT (0-2.0): The component was not taken from a real engineering system.

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2. By using the CAM system available in the manufacturing laboratory, teams must design the entire manufacturing process of the proposed component. This step involves using a large part of the content of the course, specifically: selection of cutting tools, determination of basic process parameters, calculation of operating parameters, definition of sequences of operations, determination of convenient machining strategies and process safety analysis.

ADVANCED (4.6-5.0): Selection of cutting tools is adequate and follows the rationale of tools manufacturer. Determination of basic process parameters and operation parameters is correct and properly justified. Sequence of operations is flawless and assure a successful manufacturing. Machining strategies are time and quality effective. There are not collisions or excessive proximity between tools and fixtures.

INTERMEDIATE (3.6-4.5): Selection of cutting tools is adequate and follows the rationale of tools manufacturer. Determination of basic process parameters and operation parameters is correct and acceptably justified. Sequence of operations is convenient and the manufacturing is realizable. Machining strategies are not optimal but are time and quality convenient. There are not collisions or excessive proximity between tools and fixtures.

BASIC (2.1-3.5): Selection of cutting tools is adequate and follows the rationale of tools manufacturer. Determination of basic process parameters and operation parameters is correct and acceptably justified. Sequence of operations not assures a successful manufacturing. Machining strategies are neither optimal nor time and quality convenient. There are not collisions verification evidence.

INSUFFICIENT (0-2.0): Selection of cutting tools is not adequate and dismiss the rationale of tools manufacturer. Determination of basic process parameters and operation parameters presents mistakes. Sequence of operations not assures a successful manufacturing. Machining strategies are neither optimal nor time and quality convenient. There are not collisions verification evidence.

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3. Using virtual models of numerical control (CNC) machine tools available in the laboratory and implemented in the CAM system, the teams must perform the modelling and simulation of the setup and the complete manufacturing machining process of the selected component.

ADVANCED (4.6-5.0): The team implemented in the CAM system the virtual models of the laboratory CNC machine tools. The team modeled all the necessary fixtures for setup the manufacturing processes. The team simulated the entire manufacturing process and generated CNC code that is compatible with the CNC machine tools of the laboratory.

INTERMEDIATE (3.6-4.5): The team implemented in the CAM system the virtual models of the laboratory CNC machine tools. The team modeled almost all the necessary fixtures for setup the manufacturing processes. The team simulated the entire manufacturing process and generated CNC code that is compatible with the CNC machine tools of the laboratory.

BASIC (2.1-3.5): The team implemented in the CAM system the virtual models of the laboratory CNC machine tools. The team modeled all or almost all the necessary fixtures for setup the manufacturing processes. The team simulated the entire manufacturing process and generated CNC code but it is not compatible with the CNC machine tools of the laboratory.

INSUFFICIENT (0-2.0): The team did not implement in the CAM system the virtual models of the laboratory CNC machine tools. The team did not model all the necessary fixtures for setup the manufacturing processes. The team simulated the entire manufacturing process and generated CNC code but it is not compatible with the CNC machine tools of the laboratory.

ANNEX D - Rubric for project presentation assessment

Oral presentation assessment

GROUP:							
	Advanced	Proficient	Basic	Minimum	Deficient		**Result**
	5	4	3	2	1		
The group in general ...							
1.	Formulated an introduction that guided the audience on the subject						
2.	Used an effective organizational pattern and according to the rules						
3.	Used innovative and adequate support material						
4.	Developed a conclusion consistent with the introduction and closed appropriately						
5.	Demonstrated proper use of oral and written language						
7.	Used body communication that supported the communicated ideas						
8.	Adapted the presentation successfully to the audience						
9.	Got an interesting presentation						
Total score							
Total score divided by the number of categories							

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ANNEX E - The team roles as presented in UKCES (2004)

A. ENCOURAGER: Energises groups when motivation is low through humour or through being enthusiastic. They are positive individuals who support and praise other group members. They don't like sitting around. They like to move things along by suggesting ideas, by clarifying the ideas of others and by confronting problems. They may use humour to break tensions in the group.

They may say:

"*We CAN do this!*"

"*That's a great idea!*" (p. 1)

B. COMPROMISER: Tries to maintain harmony among the team members. They are sociable, interested in others and will introduce people, draw them out and make them feel comfortable. They may be willing to change their own views to get a group decision. They work well with different people and can be depended on to promote a positive atmosphere, helping the team to gel. They pull people and tasks together thereby developing rapport. They are tolerant individuals and good listeners who will listen carefully to the views of other group members. They are good judges of people, diplomatic and sensitive to the feelings of others and not seen as a threat. They are able to recognise and resolve differences of opinion and the development of conflict, they enable "difficult" team-members to contribute positively.

They may say:

"*We haven't heard from Mike yet: I'd like to hear what you think about this.*"

"*I'm not sure I agree. What are your reasons for saying that?*" (p. 1)

C. LEADER: Good leaders direct the sequence of steps the group takes and keep the group "on-track". They are good at controlling people and events and coordinating resources. They have the energy, determination and initiative to overcome obstacles and bring competitive drive to the team. They give shape to the team effort. They recognise the skills of each individual and how they can be used. Leaders are outgoing individuals who have to be careful not to be domineering. They can sometimes steamroller the team but get results quickly. They may become impatient with complacency and lack of progress and may sometimes overreact.

They may say:

"*Let's come back to this later if we have time.*"

"*We need to move on to the next step.*"

"*Sue, what do you think about this idea?*" (p. 1)

D. SUMMARISER/CLARIFIER: Calm, reflective individuals who summarise the group's discussion and conclusions. They clarify group objectives and elaborate on the ideas of others. They may go into detail about how the group's plans would work and tie up loose ends. They are good mediators and seek consensus.

They may say:

"*So here's what we've decided so far*"

"*I think you're right, but we could also add ....*" (p. 1)

E. IDEAS PERSON: The ideas person suggests new ideas to solve group problems or suggests new ways for the group to organize the task. They dislike orthodoxy and are not too concerned with practicalities. They provide suggestions and proposals that are often original and radical. They are more concerned with the big picture than with details. They may get bored after the initial impetus wears off.

They may say:

"*Why don't we consider doing it this way?*" (p. 1)

F. EVALUATOR: Evaluators help the group to avoid coming to agreement too quickly. They tend to be slow in coming to a decision because of a need to think things over. They are the logical, analytical, objective people in the team and offer measured, dispassionate critical analysis. They contribute at times of crucial decision making because they are capable of evaluating competing proposals. They may suggest alternative ideas.

They may say:

"*What other possibilities are there?*"

or "*Let's try to look at this another way.*"

or "*I'm not sure we're on the right track.*" (p. 1)

G. RECORDER: The recorder keeps the group focused and organised. They make sure that everyone is helping with the project. They are usually the first person to offer to take notes to keep a record of ideas and decisions. They also like to act as time-keeper, to allocate times to specific tasks and remind the team to keep to them, or act as a spokesperson, to deliver the ideas and findings of the group. They may check that all members understand and agree on plans and actions and know their roles and responsibilities. They act as the memory of the group.

They may say:

"*We only have five minutes left, so we need to come to agreement now!*"

"*Do we all understand this chart?*"

"*Are we all in agreement on this?*" (p. 1)