Team formation on the basis of Belbin's roles to enhance students' performance in project based learning

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ABSTRACT

This paper presents a method that instructors have designed and implemented to form balanced teams based on Belbin's roles, with the aim of boosting positive interdependence and individual accountability within the teams and improving their performance in a project-based learning environment. Students' performance has been measured through the scores obtained during the project, individual exam and Individual Accountability Factor (IAF) and compared with cohorts of previous years, in which team composition was self-selected by students. Belbin teams (18/19–19/20) have performed significantly better than self-selected teams (16/17–17/18). Additionally, students' feedback experience and opinion has been collected. Students belonging to Belbin teams acknowledge that they attend classes more regularly, they need less time for study outside the classes and they show a higher interest for the subject at the end of the course. They also agree that working on Belbin teams has helped them to mainly improve interpersonal relationships and social skills, followed by positive interdependence and individual accountability. This team forming method gives students the opportunity to identify their own strengths and weaknesses and understand the roles (behaviours) of their teammates as well as their strengths and weaknesses. Besides, it encourages learners to focus explicitly on group work skills.

1. Introduction

Currently, the ability to communicate and to work effectively in a team is one of the most demanded skills by engineering companies (Loughry et al., 2014; Oakley et al., 2004; Zhang et al., 2020). It is also addressed as one of the key outcomes required for the accreditation of engineering programs (ABET, 2020, EFCE, 2020). From an educational point of view, the benefits of team-based learning have been widely documented (Oakley et al., 2004; León-del-Barco et al., 2018). Traditionally, in chemical engineering programs, teamwork has been especially associated with subjects such as chemical engineering laboratory (Vasquez et al., 2020, Burkholder et al., 2021) and senior design projects (Dutson, et al., 1997, Jenkins and Lackey, 2005). In the last decade, a trend to modify the lecture-based teaching into more active ways of teaching has gained importance. One of the approaches to active and cooperative learning is Problem/Project based learning (PBL) using real-world problems (Jonassen and Hung, 2008; Aranzabal, 2014; Ballesteros et al., 2019; Fini et al., 2018; Glassey, 2018; Vesikivi et al., 2020; Zhang et al., 2020).

The difficulties and challenges that students' teams must face are many, especially if they have little experience in teamwork and if no guidance or support is provided (Oakley et al., 2004). Some of the main factors affecting a proper development of teamwork are (Aritzeta et al., 2005; León del Barco et al., 2017; Leung, 2017; Loughry et al., 2014; Oakley et al., 2004; Pieterse and Thompson, 2010; Prichard and Stanton, 1999): group composition, different motivation, expectations or commitment within teammates, personality clashes, dominant and passive members, little or absence of guidance, task ambiguity, role ambiguity, academic disparity, resistance to teamwork, lack of interpersonal skills, lack of group norms, etc. Among them, interpersonal conflicts related to an unequal effort and contribution of the team members and poor time management are highlighted (Aranzabal et al., 2019). Therefore, training students in teamwork skills is crucial, although some resistance from instructors and institutions are reported in the literature, which are related to already fixed and full programs, lack of time for developing specific teamwork courses or lessons within a subject and lack of instructors' skills and fears, among others (Loughry et al., 2014; Mounir et al., 2018).

Several strategies are suggested in the literature in order to enhance teamwork (Vasquez et al., 2020; Leung, 2017; Loughry et al., 2014;

Batenburg et al., 2013; Oakley et al., 2004): keep the size of the group small, process group and individual contributions, coaching sessions, reflective sessions about teamwork, formal and informal communication, provide feedback about both individual and collective performance within a team, self- and peer assessment, incentives, gamification, team forming, etc.

Furthermore, one of the key factors for effective teamwork, especially for long-term projects, is team forming, as a potential method for boosting positive interdependence and individual accountability within the team (Loughry et al., 2014). Team forming and team management processes are specifically targeted to satisfy two types of assets: i) groups must have sufficient intellectual resources to complete their assigned tasks; ii) the members must interact with each other in productive ways (Michaelsen et al., 2014). Although, different experiences on team forming can be found in the literature, there is no clear evidence to support the best method for forming effective teams, in terms of improving overall team performance and achievement of project results. Therefore, it is often a matter of debate among faculty members.

Three ways for team forming are well established in the literature (Hilton and Phillips, 2010; Leung, 2017; Oakley et al., 2004; Pieterse and Thompson, 2010; Vasquez et al., 2020): random-, student (self)-, and, instructor-selection. By random selection, all teams have equal opportunities to succeed or fail (Pieterse and Thompson, 2010). It is very easy and quick to implement and it is useful for short-term tasks. Self-selection allows students to decide the members of their team. Students might form teams based on friendships, on geographical proximity, on similar class schedule, or even on individuals' estimates of how other students can help them get a good grade on the team assignment. If the members know each other personally, they know in advance each other's strengths and weaknesses, as well as each other's out of class demands. This often leads to teams unbalanced in skills, abilities, specialism, gender, or ethnic background and, thus, it limits learning opportunities (McGourty and Demeuse, 2001; Loughry et al., 2014; Pieterse and Thompson, 2010). Chapman et al. (2006) collected better team experiences among self-selected groups than among randomly selected groups.

There is some evidences that heterogeneous groups are more productive and better suited for multidimensional tasks (Barkley et al., 2005). Oakley et al. (2004) strongly encourage forming instructor-selected balanced teams rather than allowing students to self-select. Borges et al. (2009) found that balanced groups had a better teamwork experience as measured by higher project final marks than self-selected groups. But there are some disadvantages, e.g. students can be uncomfortable with the diversity of opinion and the possible tension that results from disagreement. In the research of Hilton and Phillips (2010), based on student's perceptions, instructor-assigned "balanced" groups reported that they got off to a slow start and, throughout the project, they had difficulties scheduling meetings. On the contrary, self-selected groups highlighted as the advantage the fact they were familiar and comfortable with one another facilitated a quicker start. They also found it easier to arrange meetings. Close to the end of the project, instructor-selected "balanced" teams felt they were able to recognize members' relative strengths and assign their work accordingly, that is, they were able to create task interdependencies. Despite these differences, Hilton and Phillips (2010) found no significant differences in group project grades between student-selected groups and instructor-selected groups. Muller (1989) compared a team forming method that achieves a balanced distribution of student skills, with a random assignment method, and the results revealed a modest improvement in student satisfaction when groups were balanced.

On the other hand, Barkley et al. (2005) reported that homogenous grouping offers advantages in some kinds of learning activities; i.e., carrying out highly structured skill development tasks, such as language learning, since learners can communicate with each other on a similar level of knowledge.

To facilitate balanced team assignments, the instructor should collect information regarding the students' backgrounds very early in the semester, for example through a questionnaire that students complete at the beginning of the course (McGourty and Demeuse, 2001). Some of the many methods and tools reported in the literature to form balanced teams are based on learning styles and personalities, academic performance in terms of grade point average (GPA) and survey ratings on different types of skills (Farland et al., 2019; Odell, 2018; Vasquez et al., 2020). One of the best-known personality tests is the Myers-Briggs Type Indicator (MBTI), which is a self-report inventory designed to identify an individual's personality type, strengths, and preferences (Bullen and Wood, 2006). Other inventories based on personality are (Aritzeta et al., 2005, 2007; Loughry et al., 2014): Kirton's Adaption-Innovation Inventory (KAI), 16 Personality Factor Questionnaire (16PF), Occupational Personality Questionnaire (OPQ) and Big Five.

Another widely accepted team forming tool is based on role taxonomy. There are several research studies based on team roles, which have been reviewed by Mathieu et al. (2015). Some of the most recent ones are based on the roles proposed by Mumford et al. (2008) (contractor, calibrator, completer, creator, contributor, critic, communicator, cooperator, collector and consult) and by Mathieu et al. (2015) (organizer, doer, challenger, innovator, team builder and connector). But, among them, Belbin role theory (Belbin, 2010) is accepted worldwide, especially in counselling, development, and management fields, which is also experiencing an increasing interest in higher education (Gutiérrez et al., 2019; Meslec and Curşeu, 2015).

In this paper, we explain the design and implementation of a method for introducing students to Belbin's role theory and subsequently forming balanced teams in Belbin's roles, with the aim of boosting positive interdependence and individual accountability within the teams and improving their performance in a project-based learning environment in the subject "Process and Product Engineering" of the Chemical Engineering Degree Program at the University of the Basque Country (UPV/EHU), Spain. The students' performance has been assessed and compared with a previous cohort, in which the self-selection method was used, to see the impact of the implementation. Students' feedback experience and opinion has also been compared.

2. Belbin role theory and related works

Belbin defines a team role as "a tendency to behave, contribute and interrelate with others in a particular way" (Belbin, 2010). Role behaviour is influenced by six factors (Aritzeta et al., 2007; Belbin, 2013; Lupuleac et al., 2012; Van de Water et al., 2008): (1) personality, (2) mental abilities, (3) current values and motivation, (4) field constraints or external working environment, (5) personal experience and cultural factors, and (6) role learning. Although personality is one of the features that may affect role behaviour, both terms should not be confused. Behaviour is observable and more flexible to contextual changes, whereas personality is more stable (resistant to changes by training) (Van de Water et al., 2008) and usually rooted in internal knowledge of an individual (not observable or visible) (Aritzeta et al., 2005). Belbin team roles should also be distinguished from functional roles (determined by their professional and/or technical skills and knowledge). For example, the style of leadership will be different depending on the type of behavioural role of the leader. Consequently, several people may play the same functional role within a team, but at the same time, they can show different behavioural team roles (Aritzeta et al., 2007). Hence, teams need a suitable balance between both functional and team roles, which are directly linked to the goals and tasks within a team (Prichard and Stanton, 1999).

It should be mentioned that Belbin is not intrinsically looking for behavioural patterns (roles), but for the ways in which these roles develop, change and interact with other team roles (Aritzeta et al., 2007). Thus, the way team members make decisions, how they interact with one another and how they apply their capabilities to achieve team results (rather than intellect or individual performance) will determine

the success or failure of a team (Batenburg et al., 2013; Van de Water et al., 2008).

Belbin has categorized individual behaviour within the team into nine roles, grouped into three main clusters (Aritzeta et al., 2005, 2007; Belbin, 2013; McHarg et al., 2012): thinking/problem solving-oriented roles (Plant, Monitor Evaluator, Specialist), people-oriented roles (Coordinator, Teamworker, Resource Investigator) and action-oriented roles (Shaper, Implementer, Completer or Finisher). Information on the main features of each function is broadly available in the literature. Table S1 (in Supplementary Information) summarizes the main features of each role, including objectives, strengths, allowed and non-negotiable weaknesses and compatibilities with other team roles.

It is important to note that an individual can develop more than one role within a team (typically 2 or 3 roles) (Henry and Stevens, 1998), although not all of them are equally prevalent. Preferred roles are those that come naturally or the individual is comfortable with. Manageable roles are those, which an individual can assume if needed; and least preferred roles, are those, which the individual does not naturally assume. Any individual should avoid playing the latter ones within a team (Aritzeta et al., 2007; Belbin, 2013). Thus, teams do not necessarily need to be composed of nine members. Usually the size of the group is kept small (three to five students) depending on the nature of the task (Breitenecker, 2014; Oakley et al., 2004), but when the size decreases below 5 the desired natural (Belbin) team role and functional skills cannot always be covered (Bullen and Wood, 2006).

Belbin Team Role Self-Perception Inventory (BTRSPI) is now one the most widely used tools for identifying the relative strength of an individual's team role preferences or affinity, with a view to forming and maintaining teams that are strong in all the team role areas (Aritzeta et al., 2005).

Belbin defends the so-called role balance hypothesis: a team showing a balanced representation of all team roles will have a greater propensity to perform highly (Prichard and Stanton, 1999). Diversity of team roles in teams is of great importance, as it contributes to (Pollock, 2009): define responsibilities, create innovation, and provide clear understanding of the tasks and team goals. Belbin also highlighted the importance of shared leadership, since each role is relevant depending on each stage of the teamwork (Aritzeta et al., 2007). In the early stages, i.e. in the stages of identifying needs and searching for ideas, the members whose preferred roles are Sharper, Coordinator, Resource Investigator and Plant are most needed. In the stage for formulating plans, two activities help to turn ideas into plans. One is to balance the options and the other is to properly use the experiences and knowledge to ensure a good decision. The Monitors-Evaluators make good long-term plans and the Specialists provide the right knowledge or know how to find it, but the best roles to turn ideas into procedures, methods and practices are Implementer and Coordinator. Resource Investigator and Teamworker are good at interpersonal skills and making contacts outside the team. In the later stages, where the tasks must be completed, the Finisher and Implementer roles are more relevant than the others.

Belbin's team roles are directly linked to some elements of team effectiveness mentioned before, such as, clarity of roles (individually and within the team), meeting goals and satisfaction of team members (Pollock, 2009). According to the literature, balanced teams are usually more effective in terms of leadership, competence, motivation, achieving goals, communication, skills, and creativity. However, a direct correlation between team role diversity and teamwork effectiveness is still unclear (Batenburg et al., 2013; Van de Water et al., 2008).

Johansen (2003) reported that the duplication of roles within a team might not necessarily contribute negatively: groups with a sole Shaper should be formed in order to avoid conflicts; while more than one Plant could improve innovation within a team (Henry and Stevens, 1998). Pollock (2009) concluded that role diversity did not have a significant influence on the effectiveness of the team; however, according to their study the presence of certain roles (i.e Shaper, Coordinator and Completer/Finisher), could enhance group effectiveness. Henry and Stevens

(1998) and Lupuleac et al. (2012) observed that in role balanced teams, the teammates were happier and more motivated, which enhanced team viability and productivity, while Torres et al. (2017) concluded that unbalanced groups gave way to an inadequate interaction and poor efficiency in collaborative work. Aguilar et al. (2019) reported that the collaboration and decision-making skills presented by groups formed based on Belbin roles were significantly greater than those presented by the groups formed based on functional roles. However, some other studies stated that Belbin's allowed weaknesses could interfere negatively in the environment of the team, as well as in decision making (Johansen, 2003).

Smith et al. (2012) applied Belbin's role theory to form teams for PBL into a large group (145) on level 2 of undergraduate module entitled Environmental Management, and found better group performance compared with that of previous years (self-selected groups), with a significant increase in first-class grades. Students also recognized the value of their Belbin report when entering the job market. However, McHarg et al. (2012) found no better group functionality among Belbin teams with respect to non-Belbin control groups (randomly assigned), in the field of dental education.

3. Problem background

For many years, the teaching and learning methodology of the first half (4.5 ECTS, 5th semester) of the subject "Process and Product Engineering" of the Chemical Engineering Bachelor Programme at the University of the Basque Country (UPV/EHU) has been based on Project Based Learning (PBL). Students' teams are asked to develop a base case design project of an industrial chemical process, including its economic and profitability analysis, i.e., the production of cumene, production of styrene, production of biodiesel, etc. (Turton et al., 2013), divided into five milestones (and their corresponding deliverables). Traditionally, up until the 2017/18 academic year, students were allowed to form 5-membered teams by themselves (self-selection method). Throughout the years, as the instructors were gaining experience, we introduced different types of strategies for providing students the information and guidance for the development of teamwork skills and to ensure the five ingredients of cooperative learning (Johnson and Johnson, 2009).

However, we observed that some students within self-selected teams faced the same teamwork difficulties described above and resulted in unpleasant learning experiences. Then, the instructor's next step was to intervene in the team forming process in order to form balanced teams, in which positive interdependence and individual accountability would be fostered, and result in better functionality and performance of teams and individuals. We asked ourselves the following question: What attributes of the individuals should be considered to create balanced student teams? We focused on methods based on grouping students with complementary skills that would allow them to successfully tackle the different types of tasks within the project. In order to identify these skills, we interviewed former students and asked them to reflect, based on their former experience, on the type of skills that team members should bring to the team to successfully complete the project. We found that most of the suggested competencies and duties were not strictly based on technical skills and knowledge, but on transversal skills closely related to those of Bebin's roles, as shown in Table 1. This led us to explore Belbin's role theory in more detail, and to determine the extent to which Belbin's role theory could be used in the forming and management of PBL teams.

4. Design and implementation

In this section, we describe, the design and implementation of Belbin's role theory to form balanced teams, over the academic years 18/19 and 19/20, with the aim of boosting positive interdependence and individual accountability within the teams and improving their performance in a project-based learning environment. In order to clarify how

Table 1

Skills and duties needed within a team suggested by former students and their connection with Belbin roles.

Skills & Duties	Identified Belbin role
To express in a written report the ideas of 4 teammates	Coordinator
To identify objectives and results and unify them	Shaper
To be skilful in the use of computer (Excel, Word)	Specialist
To be skilful in the use of PRO II simulator	Specialist
To be patient to analyse the results given by PRO II. Focus on details	Completer/Finisher
To encourage the team	Shaper
To think about the group and make sure that all the members understand everything	Teamworker
To calm down the team	Teamworker
To be disciplined and work hard	Implementer
To find information and new sources, also ask for help	Resource Investigator
To share, relate and master the contents of different subjects	Specialist, Coordinator
To generate new ideas, and make sure that different alternative proposals are coming out	Plant
To solve conflicts and give real importance to the problems	Coordinator, Teamworker
To be able to work under pressure	Shaper

Belbin team forming implementation is integrated into the course's learning and assessment activities, this section has been divided into two parts:

1) How the course learning and assessment activities have been planned and executed since the academic year 16/17–19/20, for the first half (4.5 ECTS, 5th semester) of the subject "Process and Product Engineering" devoted to the chemical process design.
2) How Team forming method based on Belbin's role theory has been planned and executed over the academic years 18/19 and 19/20.

4.1. Course structure and implementation

Project-based-learning (PBL) is selected as the core learning approach that allows better alignment of course learning and assessment activities with the learning outcomes. This approach, based on Constructive Alignment principle (Biggs, 1996; Biggs and Tang, 2007), has been developed for core courses in engineering and chemical engineering, and specifically for process design courses (Cifrian et al., 2020). The driving force of the course is a project focused on the development of a base case design for an industrial chemical process, including its economic and profitability analysis (Seider et al., 2010; Turton et al., 2013). Some project examples are: a process for cumene, styrene or biodiesel production. The project is composed of several milestones (and their corresponding deliverables), according to the different synthesis steps proposed by Seider et al. (2010). Table 2 summarizes the learning outcomes, the milestones and grading scheme, and Table 3 shows the list of the topics covered in the course. Fig. 1 allows synchronisation within the timeline of the learning activities relating to each topic with the project milestones and the deliverables for formative evaluation. Besides which, in-class and outside-class activities have been differentiated. The activities relating to each topic (orange) and the activities for the project's milestones (yellow) have also been differentiated. The number following each activity indicates the topic (Table 3), while numbers in the project timeline refers to the milestone (Table 2). Topic related activities are: attending a lecture (L), training in simulation and design procedures (T), reading (R), watching video-tutorials (WV), Jigsaw activity (Jw), Team Games Tournaments activity (TGT).

All teaching and learning activities, resources and project development have been designed to provide the appropriate amount of scaffolding to motivate students, adjust task complexity, provide structure and reduce students' frustration (McLoughlin and Luca, 2002). Students

Table 2

Learning outcomes, project milestones, deliverables and assessment weights.

Learning outcomes	Project Milestones	Deliverables (due Date)	Assessed learning outcomes	Weight (%)
1) Search technical and scientific information	Literature Survey	1. State of the art (week #5)	1, 10–13	7%
2) Use appropriate heuristics to select the best design strategies	Eliminate differences in molecular types (chemical reaction)	2. Reactor Design and Simulation (week #8)	2, 3, 4, 5, 10–13	8%
3) Draw and interpret different flow diagrams	Matching sources and sinks (mixing, separation & recycle)	3. Separation Processes- Process Overall Design (week #11)	3, 4, 6, 10–13	14%
4) Simulate a process using a process simulator (PRO II)	Eliminate differences in composition-separation & Eliminate differences in temperature, pressure and phase			
5) Apply selectivity and conversion concepts in reactor design	Heat Integration and Heat Exchanger Network Design	4. Heat integration (week #14)	2, 7, 10–13	10%
6) Select the most appropriate design parameters for purification operations	Estimation of Capital and Manufacturing Costs	5. Project Report (including previous sections) (week #18)	1 – 13	21%
7) Develop process heat integration using Pinch methodology and design the heat exchanger network	Profitability Analysis	Individual Questionnaires (throughout the course)	1, 2, 3, 5, 6, 7, 8, 9, 10	7%
8) Estimate capital and manufacturing costs		Final individual exam (week #19)	3 - 9	33%
9) Perform the process profitability analysis				
10) Use safety and environmental protection criteria in the design of an industrial chemical process				
11. Plan activities for chemical process design.				
12. Communicate design results though technical reports				
13. Carry out the process design in a team cooperatively				

- 13.1. Contribute to group with ideas, suggestions and efforts
- 13.2. Participate in-group decision making
- 13.3. Give credit for others to contribution
- 13.4. Healthy communicate, actively listen and respect opinions, customs and individual preferences
- 13.5. Give credit for others to contribution
- 13.6. Recognize collaborators strengths and weaknesses

Table 3
Course topics.

1. Introduction to chemical product and process design. The nature of design. Classification of chemical products. Steps in product and process design. Environmental considerations. Safety considerations.
2. Process creation for basic chemicals. Preliminary database creation. Preliminary process synthesis. Synthesis steps. Gross profit. Synthesis Tree. Development of the base-case design. Flow diagrams. Flow summary table. Equipment summary table. Utilities summary Table.
3. Process simulation. Introduction. Principles of process simulators. Process and Simulation Flowsheets. Recycling streams. Solution algorithms.
4. Process synthesis heuristics. Raw materials and chemical reactions. Distribution of chemicals. Separations. Heat removal from reactors. Heat exchangers and furnaces. Pressure variation.
5. Design of reactors. Reactor evaluation. Ideal kinetic reaction models. Concentration, temperature, pressure and phases. Reactor models. Simulation.
6. Separation train synthesis. Overall configuration of separation system. Criteria for selection of separation methods. Separation factor. Distillation column design and simulation. Sequencing of ordinary distillation columns.
7. Heat integration in process plants. Minimum hot and cold utility requirements. Minimum number of heat exchangers. Pinch method.
8. Cost estimation. Capital costs. Types of estimations. Manufacturing costs: raw materials, utilities, waste treatment, operating labour. Sales.
9. Profitability analysis. Approximate profitability measures. Time value of money. Cash flow and depreciation. Rigorous profitability measures: Net Present Value (NPV) and Investor's Rate of Return (IRR or DCFRR).

must approach the project with a basic knowledge of chemistry, industrial processes and chemical engineering, learnt throughout the first four semesters, and with the knowledge gained in the course itself.

Two stages can be distinguished in the course timeline (Fig. 1). In the first stage (weeks 1–5), the learning activities are designed to provide the basic framework and tools for chemical process design (topics 1–4), in a flipped way (Karabulut-Ilgu et al., 2018): A flipped jigsaw activity (topic 2) (Kousa, 2015); a flipped Team Games Tournament (TGT) for introducing students in the use of heuristics (topic 4), and training sessions on computer aided simulation (topic 3) with SIMSCI PRO II software (Belton, 2016), based on previous watching of video-tutorials (WV) elaborated by the instructors.

The second stage (weeks 5–15) is structured to focus learning around the chemical process design project (milestones 2–5). Before undertaking each milestone, students attend a lecture and training sessions on design procedures (calculation of separation factors, determination of column pressure, equipment sizing, reactor and column simulation, cost estimation, etc.), which are related to the different synthesis steps. It also includes reading the reference literature (Seider et al., 2010; Turton et al., 2013), and sometimes watching several videos as teaching aids. The teams' first approach to the project milestones is taken in class time. Ultimately, the project allows students to contextualise previous and new knowledge in problem solving rather than information to be

learned. The authors seek to ensure that students are aware of what they know and need to know, make decisions, analyse and evaluate the results, feel contextualized in their profession, find the activity challenging and include social interaction and collaboration to solve complex problems. Overall, 46% of class time is devoted to team activities.

The specific assessment tools including goal sheets, tasks lists, templates, assessment rubrics and the feedback, immediately after the milestone's deliverable is completed, provides some guidance for scaffolding student thinking. The formative assessment is made as students go through the teaching and learning activities in which learning is applied to an action that shows the student's attainment of the learning outcomes. The rubrics the instructor uses for grading milestones reports are based on learning outcomes attainment and are public so students can self-assess the quality of their deliverable prior to submission. The milestone report delivery includes submitting to some monitoring questionnaires (MQs) straight after. The MQs allow us to process individual's knowledge on each deliverable and to incorporate the corresponding scores into each individual's project grade, by multiplying the overall team project score to the Individual Accountability Factor (IAF). Further details on MQs and IAF have been reported elsewhere (Aranzabal et al., 2019). Another common way to process individual accountability in the literature is peer-assessment (Kao, 2013, Aranzabal et al., 2019; Cifrian et al., 2020). Overall, the project accounts for the 60% of the final score.
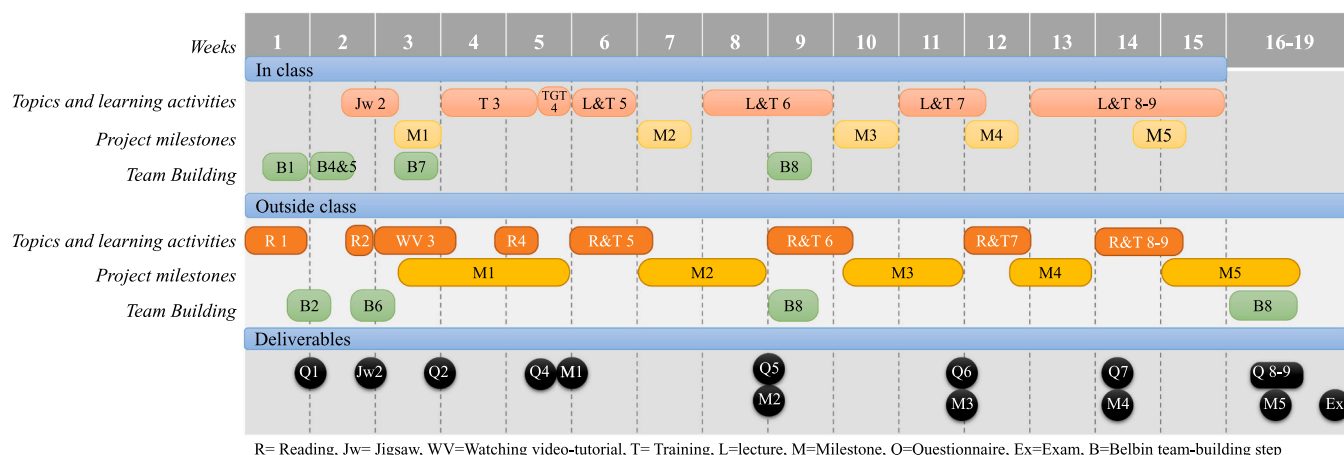
Students also answer some online questionnaires individually after completing the learning activities and the milestones related to a topic. This allows the learner to process the extent to which he/she has learned the key concepts of each topic. A second attempt is provided in questionnaires #1 and #2. These quizzes account for the 7% of the overall grading.

Finally, students take an individual final exam (33%), in order to individually assess some of the learning outcomes (#3 - #9, Table 2), which have been previously gained collectively through the design project. The minimum score is 5/10 for passing the subject.

4.2. Team forming method on the basis of Belbin's role theory

This section describes the methodology we have designed for raising student awareness about the benefits of teamwork and for forming teams based on Belbin's role theory. This methodology, composed of 8 steps (Fig. 2) has been developed for the two latest consecutive academic years, 18/19 and 19/20. Fig. 1 allows synchronising in the timeline the 8 steps with the course learning activities and assessment tasks.

In the former academic years (16/17 and 17/18), students were allowed to form their own teams according to their personal preferences

R= Reading, Jw= Jigsaw, WV=Watching video-tutorial, T= Training, L=lecture, M=Milestone, Q=Questionnaire, Ex=Exam, B=Belbin team-building step

Fig. 1. Synchronisation of learning activities, project milestones and deliverables to topics within the timeline.

1 **Raising teamwork awareness:**
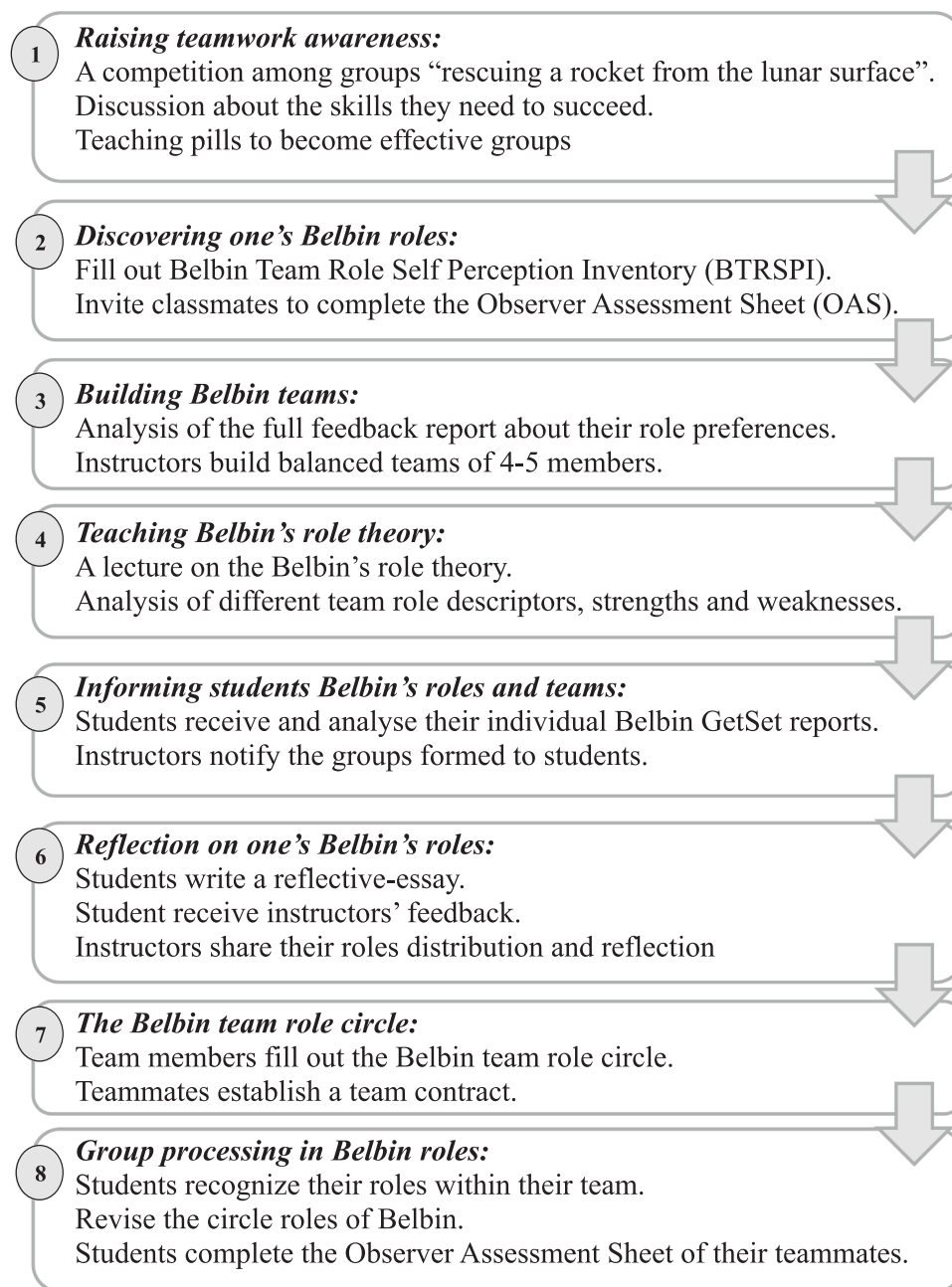A competition among groups "rescuing a rocket from the lunar surface".
Discussion about the skills they need to succeed.
Teaching pills to become effective groups

2 **Discovering one's Belbin roles:**
Fill out Belbin Team Role Self Perception Inventory (BTRSPI).
Invite classmates to complete the Observer Assessment Sheet (OAS).

3 **Building Belbin teams:**
Analysis of the full feedback report about their role preferences.
Instructors build balanced teams of 4-5 members.

4 **Teaching Belbin's role theory:**
A lecture on the Belbin's role theory.
Analysis of different team role descriptors, strengths and weaknesses.

5 **Informing students Belbin's roles and teams:**
Students receive and analyse their individual Belbin GetSet reports.
Instructors notify the groups formed to students.

6 **Reflection on one's Belbin's roles:**
Students write a reflective-essay.
Student receive instructors' feedback.
Instructors share their roles distribution and reflection

7 **The Belbin team role circle:**
Team members fill out the Belbin team role circle.
Teammates establish a team contract.

8 **Group processing in Belbin roles:**
Students recognize their roles within their team.
Revise the circle roles of Belbin.
Students complete the Observer Assessment Sheet of their teammates.

Fig. 2. Schematic procedure for team formation based on Belbin's role theory.

(self-selected teams). At that time, only two activities related to team-working were carried out: a descriptive session on how to perform effectively as a team (week #1), and a reflective session on group processing midway through project development (week #9). The other learning activities and assessment tasks (questionnaires, project milestones and exam) are the same for all the cohorts (16/17 – 19/20), as described in Section 4.1.

4.2.1. Step 1: Raising teamwork awareness

Once all the aspects related to the syllabus were established, the aim of the first session of the course was to make students aware of the importance of the complementarity of team members' skills to reach a goal. A fun competition was organized among several groups randomly formed in class with a common goal: "rescuing a rocket from the lunar surface". The materials for this exercise were provided by Belbin Spain & Latam. Teams were equipped with a rocket coupled with a timer, several

ropes of different size and a circular carpet, which emulated the lunar surface. We asked teams to form a strategy to get the rocket out of the carpet within a short timeframe, without entering the lunar surface, and exclusively making use of the ropes provided (Fig. 3). After this activity, all students together, with the instructor's guidance, discussed the skills needed to succeed in their missions and to identify their own skills and their teammates' skills during the exercise. Students highlighted the importance of transversal skills (coordination, team cohesion, respect, creativity, active listening, initiative, motivation, planning, etc.), while only few technical skills were required (physics fundamentals, making proper knots). Godskesen (2009) also reported similar conclusions in a LEGO exercise, where transversal skills outnumbered technical skills.

This session was closed by providing students some information on what makes an effective group, based on the study of Campion et al. (1993), as well as how to avoid dysfunctions within the team, based on the book of Lencioni (2002). Additional materials were also provided to

Fig. 3. A group of students struggling to rescue the rocket from the lunar surface.

reinforce the importance of effective teamwork and conflict resolution, i.e. "Coping with hitchhikers and couch potatoes on teams" by Oakley et al. (2004).

4.2.2. Step 2. Discovering one's Belbin roles

After the first training session, we asked students to complete the BTRSPI, provided by Belbin GETSET, outside the class. The BTRSPI is a computer-based questionnaire (Belbin Interplace), which measures 10 dimensions (Belbin, 2013): 9 team roles and one additional scale, which measures claims about oneself (social desirability) rather than valid team role contributions, known as dropped points (DP). The questionnaire is composed of eight sections, where a heading (scenario) and ten statements are shown for each section. The different statements include one item per team role and an additional item accounting for social desirability or DP. The headings provide different scenarios or situations, where students, based on their own experiences, can feel identified or reflected through the suggested statements. Students have to distribute 10 points in total per section, according to the strength in which they feel that the statements reflect their own behaviour. They should avoid extreme situations (10 points for a sole statement, or 1 point to each statement). Usually, two to five items are scored. Furthermore, students may answer according to how they wish to behave or be perceived, rather than how they really are (Belbin, 2013). The time estimated to complete the BTRSPI is about 15–20 mins.

Upon completion of the BTRSPI, individuals needed to invite up to 6 classmates who know them well to complete the Observer Assement Sheet (OAS) about them. This questionnaire provides a 72 items checklist divided into two parts: the first is composed of 45 positive adjectives, which are possible descriptors of the individual being observed; while the second part contains 27 negative adjectives or phrases. Each team role is scored with five positive and three negative adjectives. The observers tick the adjectives which better suit for each individual observed (Aritzeta et al., 2007). They can mark even with two ticks if the adjective represents his/her behaviour very much. It takes 5–10 min to complete. The OAS allows to some students' social desirability to be overlooked (Aritzeta et al., 2007; Belbin, 2013; Van de Water et al., 2008), and to ensure a well-rounded picture of their Belbin Team Role contribution, which considers others' views.

4.2.3. Step 3. Forming Belbin teams

Belbin GETSET system handles the norming, data analysis and complex algorithms, in order to provide a full feedback report for each student, where the team role preferences are reflected both textually and graphically (Belbin, 2013). A percentile bar chart shows the

contribution of each student's team roles from highest to lowest. This graph is a combination of one's perception (BTRSPI) and Observers' perception (OAS). The Belbin reports make use of percentiles to measure and express the strength of an individual's team role propensity relative to that of others (the rest of a given "population"). As a general term, values between 0 and 30 are considered "rejected roles", values between 31 and 70 are considered "able to be assumed roles", and values between 71 and 100 are considered "natural roles". However, not all the students achieve score of 70 in their strongest roles. For example, student A may have Completer/Finisher as his/her top team role and be in the 65th percentile for this role; although student B may have Completer/Finisher as a second role, but he or she may be in the 80th percentile. Of the two, it would be expected student B to be a stronger example of a Completer/Finisher than student A, regardless of the role ranking. Accordingly, instructors formed teams of 4–5 members considering each student's strongest 2–3 roles and their percentile score, so that the nine roles were represented in the most balanced possible way (Aritzeta et al., 2007; Van de Water et al., 2008). Gender balance was also considered. Their composition is analysed in Section 5.

4.2.4. Step 4. Teaching Belbin's role theory

The aim of the second teamwork training session was to teach students Belbin's role theory. Firstly, instructors gave a lecture on the Belbin's role theory adapted to their needs. We emphasized the importance of the strengths of each role in a balanced team and that the strengths of one role are complemented by the weaknesses of another role. Secondly, by using the jigsaw technique, students analysed different team role descriptors, strengths and weaknesses. Students understood that all the roles are important and crucial at some point throughout the project (Godskesen, 2009). They also learnt how to handle their "allowable weaknesses" and how these weaknesses could become "non-allowable" if taken to the extreme (Belbin, 2013), as detailed in Table S1.

4.2.5. Step 5. Informing students Belbin's roles and teams

After learning about Belbin's role theory, students received their individual Belbin GetSet reports. The report is set in a workbook with key points and questions designed to provoke reflection and increase self-understanding. This report includes (Belbin, 2013): (1) a Belbin team role overview; (2) "How you see yourself", team role preferences according to BTRSPI; (3) "How others see you", team role preferences according to OAS, as well as a list of observer responses, including adjectives; (4) "The complete picture", overall team role preferences by combining the team role views of the individual and their observers; (5) "Your strengths", observed team roles strengths and weaknesses; (6) "How to handle interviews", including suggested working styles; and, (7) "Your personal statement". Students had ~20 mins to read and analyse the report. Finally, the instructors notified the groups formed to students.

4.2.6. Step 6. Reflection on one's Belbin roles

Students completed a written reflective-essay, in order to check if they felt identified with their roles, by focusing on their strengths and weaknesses. Since behaviour is evidential, we encouraged them to give real everyday examples (Belbin, 2013; Leung, 2017). This task was completed outside the class and shared with the instructor afterwards. Table 4 shows, as an example, a student's reflective-essay that shows the preferred role of Finisher. The essays were not graded, but instructors provided constructive feedback to each student (see also an example in Table 4) to encourage them. Instructors also shared their role distribution and reflection, aiming to convert the class into a learning community (Oakley et al., 2004).

Table 4
An example of a student's reflective essay with the preferred role of Finisher and instructor's feedback.

Student's reflective essay

Do you feel identified with your main Belbin roles? *According to Belbin's report my two main roles are Finisher (95%) and Specialist (71%). The percentage of the Finisher role has been especially high, thus, it gives some certainty about being one of my natural roles. I consider that this role reflects my identity, since I am such a perfectionist, and I find so difficult to delegate the tasks with other people. I am used to completing the tasks with a good quality, but quite often late and out of the deadline, since I afford more work than I should. I consider myself also specialist, since I put too much interest and curiosity on the projects I am involved in, and usually, I prefer to work by myself. Therefore, I think I feel very identified with my roles within a team.* ***How others see you and why do you think so?*** *My observers also perceived that I am quite perfectionist (Finisher), Specialist and an accurate person. I was not surprised about their answers to be honest. My self-perception and observers' perception is very similar. They see me in this way, since I show my identity and behaviour naturally, although sometimes it can be a little offensive. Their point of view is directly related to the fact that I am always spending excessive time and effort looking for mistakes.* ***Do you think that you properly reflect your roles?*** *My roles are crucial for the last steps of a project, where I contribute to obtain clear and precise results. However, I think that I should participate more in the first steps of a project, and, in consequence, reflect better my roles. As a Finisher, I should work on smoothing my perfectionism, not to waste so much time. I think I should reflect on my roles to develop my work in a more integrated way, and to waste less time and effort.* ***Can you give any example?*** *Last term, in laboratory practices we completed too many laboratory technical reports. I find many examples of my roles within these tasks. For example, more than once we delivered the report late, as I needed more time to thoroughly revise it. To delegate work with my mates was very difficult for me, and often I did the work by myself without giving any explanations to my team. We obtained reasonably good marks, although we faced some unpleasant moments due to deadlines.* ***How can you contribute within your team?*** *I consider myself good at polishing and giving final details to the work. I think it can be important to deliver a task without mistakes and in a correct format. Furthermore, I can contribute to deepening in a specific topic or task.*

Instructors' feedback:

Dear student, You have provided a proper and deep analysis of your main roles, quite a perfectionist Finisher. Congratulations! We can perceive it in many aspects of your self-report. You have perfectly identified the main weakness of a Finisher. However, being perfectionist is not bad, as long as you control it and do not get bogged down with detail, or do not offend your teammates because they do not see what you see. Me, myself, I am quite a perfectionist too, though not so much a finisher, and sometimes I do not control those weaknesses either. I am more worried about the second one (offending teammates). You should try to control yourself when facing these situations. Thank you for sharing your reflections and good luck for the project! Instructor

4.2.7. Step 7. The Belbin team role circle

The third training session aimed team members to know each other from the Belbin role point of view. Team members were asked to fill the Belbin team role circle (Fig. 4), by entering their names in the segments that correspond to their preferred roles, and to introduce to each other the reflections made previously in the self-report. Once finished, this circle gave an overview of the team roles present in the team.

Subsequently, teammates established a team contract, with their own rules and guidelines. According to Oakley et al. (2004) this contract should provide some rules to assure effective team functioning, by clearly stating the different team roles and each individual's responsibilities, procedures for working on and submitting assignments.

4.2.8. Step 8. Group processing in Belbin roles

A group processing session was scheduled for week #9, after they completed the second deliverable and while involved in the third (Fig. 1). This session aimed to check whether students were able to recognize their roles within their team and to revise again the Belbin role circle, as some members might have been able to assume different roles from those identified in their initial report. Each team met with the instructor, who facilitated the meeting, for about 30 min.

Finally, before delivering the final report (week #18), students completed the OAS of their teammates. This information allowed the instructor and students to have a more realistic picture of the distribution of Belbin's roles within the teams. Students were additionally invited to write a reflective essay on their teamwork experience within
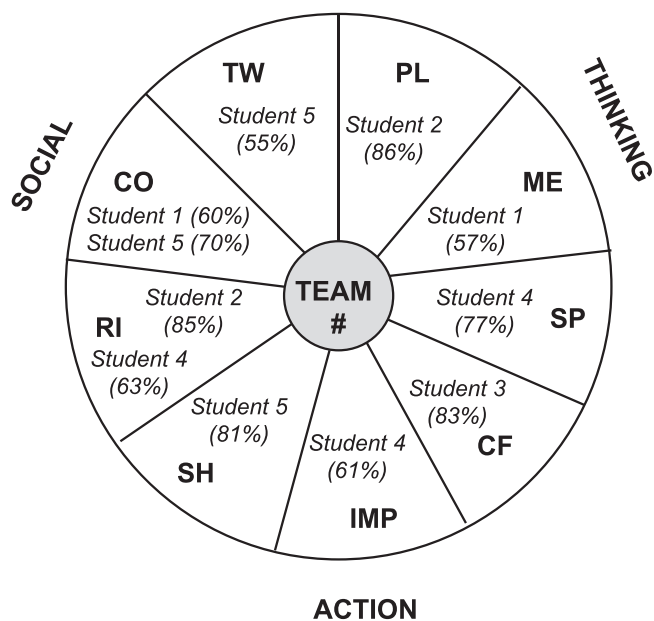

Fig. 4. An example of a team role circle.

the new framework.

5. Role distribution within the teams

This section aims to analyse the role distribution of the Belbin teams based on the data obtained from BTRSPI and OAS reports collected at the beginning and at the of the semester. Fig. 5A shows the role profiles of the five groups built in the 19/20 at the beginning of the semester, while Fig. 5B shows the resulting role profiles at the end of the semester. The role profiles of the eight groups built in the 18/19 academic year are shown, for brevity, in Fig. S1 of the Supplementary Information. The coloured dots represent each member's score in their main roles (2–3), while the dotted line indicates the group's highest score in each of the roles. As shown in Fig. 5, team role profiles have changed from the time the teams were formed to the end of the semester. This change is accepted in the literature due to several factors (Henry and Stevens, 1998; Partington and Harris, 1999): (i) an individual can fill more roles than the highest scored 2–3 roles; (ii) other fellow members can keep an individual from filling a role in the case that the fellow member is stronger in the role, especially if the member has other stronger roles; (iii) a member can assume a missing role in the group, even if it is not his or her strongest role.

The red nonagon of Fig. 5 represents the percentile 70, above which all roles are considered "natural roles". Most of the roles are represented near 70th percentile, even though not all of them exceed it. This condition is difficult to meet, due to the limited number of students in each academic year and the heterogeneous distribution of strongest roles for each student, as shown in Fig. 6.

Fig. 6 shows the first and second highest scoring role abundance for each of the academic year. In general, the most abundant roles have been Coordinator, Implementer and Completer/Finisher, while the less common roles have been Monitor-Evaluator, Shaper and Plant. However, this distribution can change from one year to another. For example, the most abundant role in 18/19 was Coordinator, but in 19/20 they were Specialist and Implementer. Likewise, the less common role in 18/19 was Monitor-Evaluator, but in 19/20 it was Shaper.

6. Impact of team forming through Belbin's role theory in teams' and individuals' performance

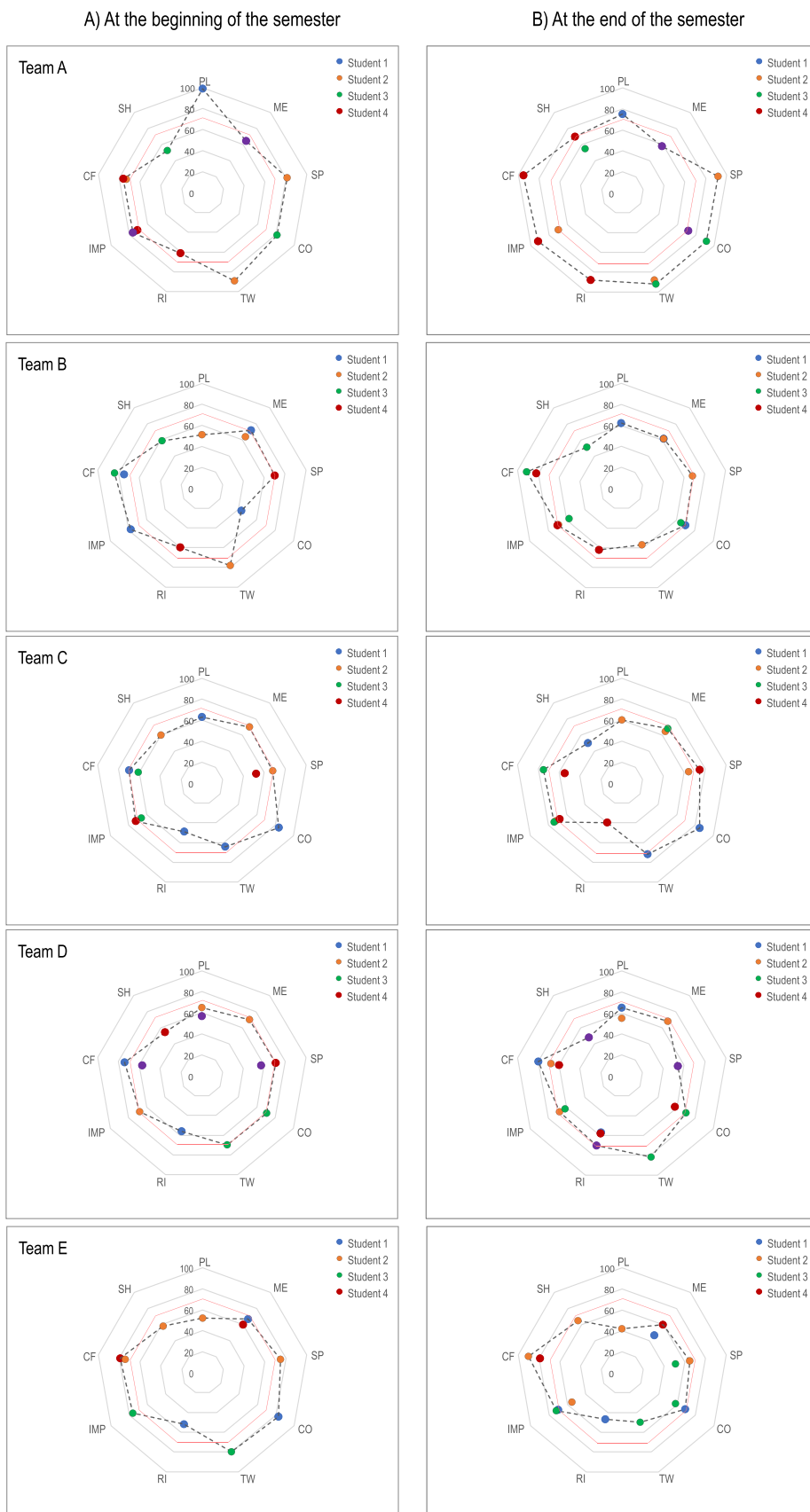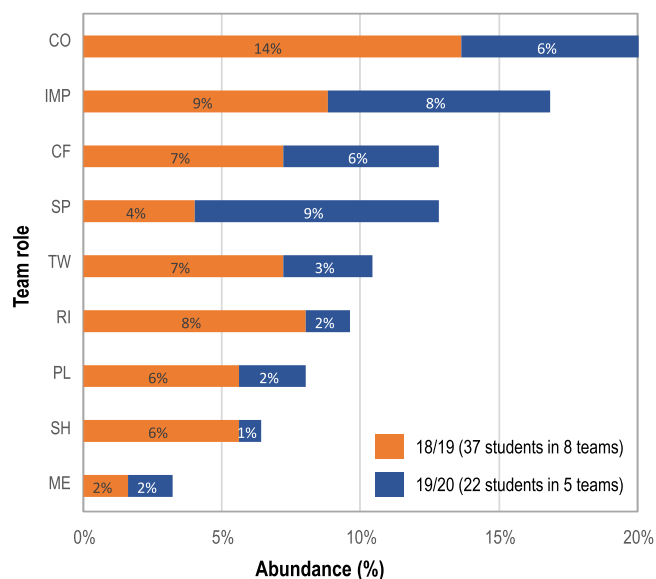Many studies on team forming have used project, reports or exam

Fig. 5. The team role profiles of the teams in the 19/20 academic year. A) at the beginning of the semester; B) at the end of the semester.

Fig. 6. Overall distribution of the strongest first and second roles (CO = Coordinator, IMP = Implementer, CF = Completer-Finisher, SP = Specialist, TW = Teamworker, RI = Resource Investigator, PL = Plant, SH = Sharper, ME = Monitor Evaluator).

scores as a measure of teams' and students' performance. (Bullen and Wood, 2006; Van der Laan Smith and Spindle, 2007; Smith et al., 2012; Vasquez et al., 2020). Other studies use students' experience and feedback, mostly based on questionnaires (Chapman et al., 2006; Hilton and Phillips, 2010; McHarg et al., 2012). In this study, both students' scores and feedback have been used to compare the performance of students grouped through Belbin's role theory (Belbin teams in academic year 18/19 and 19/20) with respect to students grouped by themselves according to their personal preferences (self-selected teams in academic years 16/17 and 17/18).

6.1. Students' performance

Performance has been measured by three different scores: (1) project score of each group member, calculated according to the weight of each deliverable (Table 2); (2) each students' exam scores; and (3) each student's IAF, which was calculated as the individual average MQs rating divided by the highest MQs rating within the team (Aranzabal et al., 2019). Table S2 (in supplementary material) collects the scores of all students for the academic years from 16/17–19/20.

Table 5 shows the three scores means and their standard deviations for Belbin (18/19 & 19/20) and self-selected teams (16/17 & 17/18). In the three measures (exam, project and IAF scores), the means for Belbin teams are higher than in self-selected teams. In order to determine if the difference between the performance means of two type of groups is significant, independent t-test was conducted. First of all, Levene's test

has been conducted to assess if the performance variances of Belbin teams and self-selected teams are equal ($p > 0.05$) or unequal ($p < 0.05$). For the case the variances of the two groups are equal, e.g. exam score, Student's t-test was performed to determine whether the difference between the means of exam score of the two type of groups (Belbin teams vs. self-selected teams) is significant ($p < 0.05$) or not ($p > 0.05$). For the cases the variance of the two groups are unequal (project score and IAF), Welch's t-test was performed. The results shown in Table 5 demonstrate that there is statistically significant difference between the means of the two groups ($p < 0.05$). The performance of students in terms of project score, exam score and IAF is significantly better for Belbin teams than for self-selected teams.

Fig. 7 compares the exam scoring distribution between two team forming strategies. The rate of students not passing the exam has decreased (from 36% to 23%), while the rate of students with "good" and "mention" grades has increased, (from 10% to 22%) by forming teams according to Belbin's theory. What is remarkable is the increase from 2% to 5% of the rate of students with "outstanding" grade. Also remarkable is the drop of the rate of students not taking the exams at the first call, from 20% in the academic years in which students were grouped by self-selection, to 7%, for the academic years in which teams were built by the instructors through Belbin's theory. This drop suggests that students working in Belbin teams feel more engaged and that their learning is higher. Therefore, students feel more confident that they can pass the exam.

Fig. 7. Comparison of the final exam scoring distribution between the students belonging to self-selected teams (16/17 & 17/18), and the students participating in Belbin teams (18/19 & 19/20).
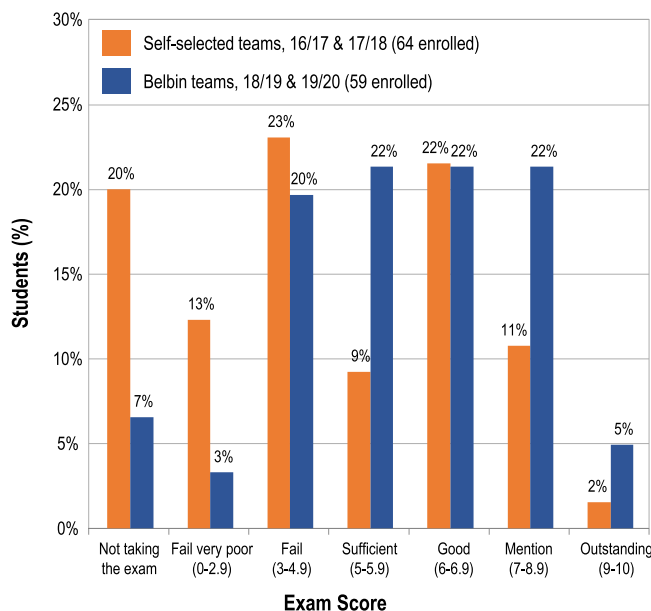
Table 5
Means, standard deviations, test of homogeneity of variances (Levene's Test), and the results of t-test for the equality of means of student's performance scores working in Belbin teams and self-selected teams.

Variable	Groups	Mean	SD	Levene's Test for equality of variances		t-Test		
				F	p-value	t	df	p-value (two-tailed)
Project Score	Belbin teams (N = 59)	7.56	0.96	5.42	4.36E-10	-2.16	85	0.03
	Self-selected teams (N = 63)	6.88	5.22					
Exam Score	Belbin teams (N = 59)	5.47	5.17	1.50	0.065	-2.74	120	0.007
	Self-selected teams (N = 63)	4.20	7.77					
IAF[a]	Belbin teams (N = 59)	0.88	0.01	4.491	2.68E-07	-2.45	43	0.02
	Self-selected teams (N = 35)	0.77	0.06					

[a] IAF is a measure that has been collected from academic year 17/18 onwards.

IAF is a measure of students' performance very related to their performance and engagement to the teamwork, as stated in Section 4 (Aranzabal et al., 2019). Fig. 8 compares the IAF rating distribution between two team forming strategies, categorized into four levels: "Very low engagement" (IAF = 0 – 0.3); "low engagement" (IAF = 0.31 – 0.60); "regular engagement" (IAF = 0.61 – 0.80); "high engagement" (IAF = 0.81 – 1.0). The results show that "high engagement" increases from 54% (self-selected teams) to 76% (Belbin teams), while "low" decreases from 11% to 3% and "very low engagement" declines from 14% to 0%. These results show that forming teams by Belbin's role theory improves the positive interdependence and individual accountability of team members, which, in turn, allows improving team and individual performance, as shown in Figs. 7 and 8.

6.2. Students' feedback experience and opinion

Students' feedback experience and opinion was collected through two types of questionnaires. The first one is formally conducted by the University of the Basque Country (UPV/EHU) every semester at the end of each subject-teaching period, as many universities do (Marsh, 1984; Marsh and Hocevar, 1991), so that students can assess their instructor's teaching quality. This questionnaire initially collects information to contextualize the results derived from it: sex, age, rate of class attendance, the average study time per week, interest in the subject after having studied it with the instructor, etc., before submitting students to the questions related to the instructor's teaching quality. Although it is worth comparing the results of all the items between the courses in which Belbin's theory was used and those in which it was not, the items "class attendance", "interest in the subject" and "average study time" were selected to be analysed specifically, because they are related to students' performance and engagement. Table 6 and Figs. 9 and 10 show students' opinion about these three items.

Table 6 shows the students' perception about their class attendance rate among the following options: 0–25%, 26–50%, 51–75%, 76–100%. Student's responses show that class attendance has increased for the academic years that students are working in Belbin teams. Furthermore, students' perception about their attendance rate is also coherent with the class attendance registered by the instructors, which have been steadily increasing for the last four academic courses: 89.3% (16/17),
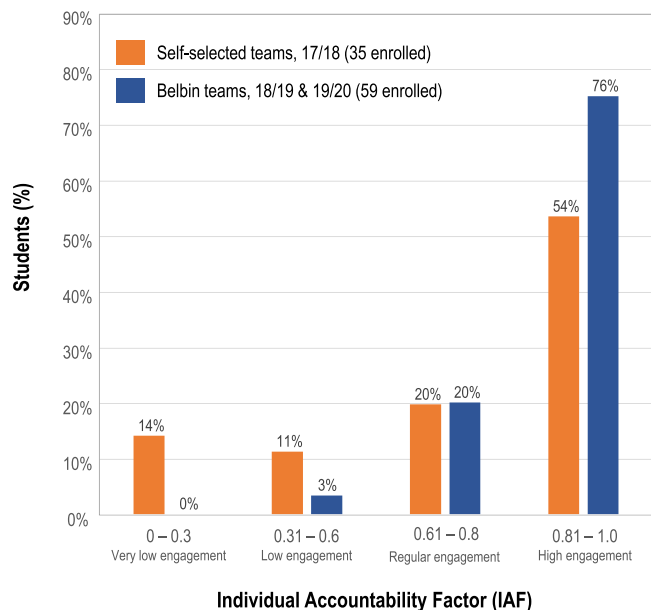
Table 6
Rate of students taking class attendance as a function of type of teams and academic years, obtained from students' feedback.

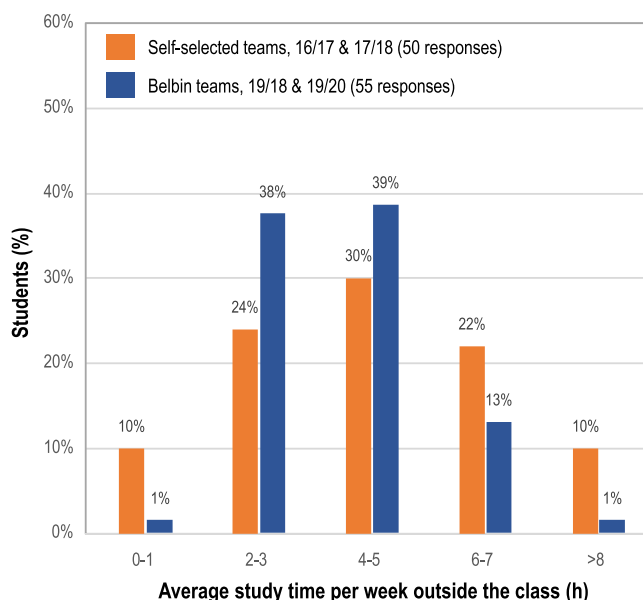| Type of teams	Self-selected teams	Belbin teams
Academic years	16/17 & 17/18	18/19 & 19/20
	Percentage distribution of responses	
0–25%	0.0	1.5
26–50%	2.0	0.0
51–75%	10.0	4.5
76–100%	88.0	94.1
No. students filling the survey	50	55

Fig. 9. Comparison of the average study per week outside the class students acknowledge between the students belonging to self-selected teams (16/17 & 17/18), and the students participating in Belbin teams (18/19 & 19/20).
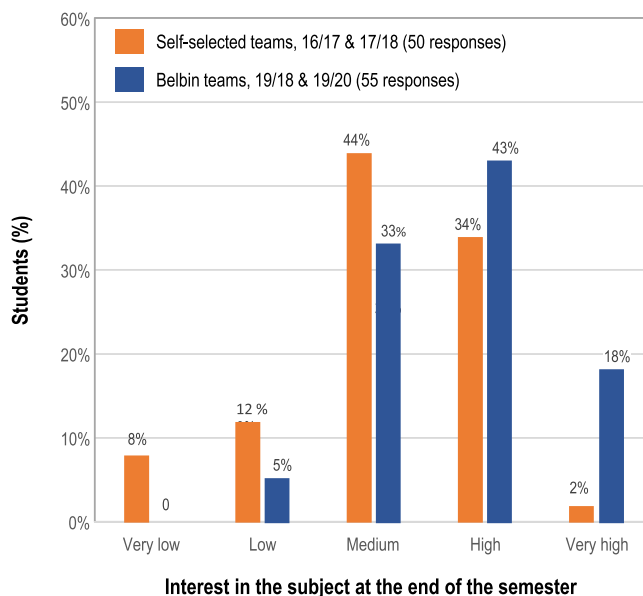

Fig. 8. Comparison of the IAF between the students belonging to self-selected teams (17/18), and the students participating in Belbin teams (18/19 & 19/20). IAF is a measure that has been collected from academic year 17/18 onwards.

Fig. 10. Interest in the subject (at the end of the semester) shown by students belonging to self-selected teams (16/17 & 17/18) and those belonging to Belbin teams (18/19 & 19/20).

88.1% (17/18), 92.4% (18/19) and 99.5% (19/20).

Class attendance can vary considerably across countries, universities, and subjects, because many factors can influence the level of attendance, including university culture, socio-economic factors, student factors, workload, teaching methods, and the teacher (Kirby and McElroy, 2003; Lukkarinen et al., 2016). This relevant issue has concerned the authors for a long time, among others, because in the Spanish Higher Education System attendance is not mandatory. However, in the present subject, with a team-based PBL approach, class attendance is essential for a good team performance. For the time instructors have been teaching the subject, (2013–2021), no incentive was offered for class attendance (i.e. small symbolic increment to their grade), other than the positive interdependence generated by working in teams.

Fig. 9 compares the average study per week outside the class students acknowledge in the two categories. The median is on 4–5 h per week. The rate of students that have spent 6–7 h has decreased from 22% to 13% and the rate of those who have spent more than 8 h has decreased from 10% to 1%. Conversely, the rate of students who have spent 2–3 h and 4–5 h has increased from 24% to 38% and from 30 to 39%, respectively. The lower average study time per week outside the class can be related to the higher rate of class attendance and with the higher marks for the students arranged in Belbin's shown in Section 6.1 (Kirby and McElroy, 2003; Lukkarinen et al., 2016).

Fig. 10 shows students' responses about "their interest in the subject matter after having taken the course", which have also been measured by several researchers as another indicator of student's engagement (Heller et al., 2010; Freeman et al., 2014; Ketonen et al., 2016; Glassey, 2018). The rate of students who showed "high" and "very high" interest increased by a factor of 1.3 and 9.0, respectively, among students arranged in Belbin-type teams, while the "medium", "low" and "very low" interest decreased.

The better feedback opinion of students that were organized in Belbin teams with respect to self-selected teams, on these three important issues of their learning process is coherent with the better performance shown in Section 6.1.

The second survey was an ad hoc questionnaire, adapted from Chica (2011) and composed of 23 items, in which students were asked to rate, by means of a Likert scale, whether team forming according to Belbin's role theory helped them at both group work and personal level. Table 7 shows the students opinion in two ways: 1) percentage distribution, 2) mean and standard deviation (SD). The items have been ordered from the highest to the lowest rated items.Most of the students (> 50%) agree and strongly agree that team forming by Belbin's theory has favoured all aspects of Table 7 except for item "The organization of my time and tasks" (#23). The highest rated item (highest mean and lowest SD) is "The ability to listen to the opinions of others" (90% of students agree and strongly agree). It is followed by the next items successively (80–84% of the students have marked "agree" and "strongly agree"): "The ability to draw on the knowledge, ideas and skills of others", "The communication of my ideas, knowledge, proposals, etc.", "The integration of colleagues in a common work", "The ability to accept and welcome proposals from other colleagues even if they are different from mine", "My perception of other lesser-known colleagues" and "Consensus decision-making in the group". Accordingly, the rating of these items is also less dispersed, that their SD is the lowest. In general terms, the items associated to group work are rated higher than the items associated to personal level.

The items of Table 7 have been classified into four categories associated with group work: interpersonal relationships (IR), positive interdependence (PI), individual accountability (IA) and personal level (PL). Fig. 11 shows the response distribution of the items grouped into these categories. It is evident that items students believe have been most favoured by team forming through Belbin's theory are those associated with positive interdependence (#2, #4, #5, #6, #7, #10, #12, #13, #14, #15) and interpersonal relationships (#1, #3, #5, #9, #18, #20), followed by the items associated with individual accountability (#11,

Table 7

Students' feedback experience and opinion on whether forming student groups using Belbin's role theory helped them on group work and at personal level (49 responses in 18/19 and 19/20).

Do you agree that team forming through Belbin's role theory has favoured the following aspects of your team and personal work?	Category[a]	Students' percentage distribution[b]					Mean	SD
		1	2	3	4	5		
01. The ability to listen to the opinions of others	IR	0	2	8	66	24	4.1	0.62
02. The ability to draw on the knowledge, ideas and skills of others	PI	0	2	16	54	28	4.1	0.72
03. The communication of my ideas, knowledge, proposals, etc.	IR	0	0	16	66	18	4.0	0.58
04. The integration of colleagues in a common work	PI	2	0	14	64	20	4.0	0.72
05. The ability to accept and welcome proposals from other colleagues even if they are different from mine	IR,PI	0	4	16	56	24	4.0	0.75
06. My perception of other lesser-known colleagues	PI	0	6	14	50	30	4.0	0.82
07. Consensus decision-making in the group	PI	0	4	14	71	10	3.9	0.63
08. Improve my overall learning	PL	0	6	20	52	22	3.9	0.81
09. Resolving internal conflicts in a flexible way and with constructive dialogue	IR	2	2	28	44	24	3.9	0.87
10. Trust in other colleagues	PI	6	4	16	46	28	3.9	1.06
11. Balancing the contributions of team members	IA	0	4	24	60	12	3.8	0.69
12. Cohesion between the group's members	PI	0	6	24	52	18	3.8	0.79
13. Respect the group's working times	PI	2	4	22	58	14	3.8	0.81
14. Commitment to the outcome of the final work	PI,IA	2	6	18	54	20	3.8	0.88
15 The involvement of the group to achieve a goal	PI	0	8	28	42	22	3.8	0.88
16. Responsibility for individual tasks	IA	2	8	22	51	16	3.7	0.90
17. Improve the level of self-confidence	PL	4	4	22	54	16	3.7	0.91
18. Improve deliverable's outcomes	IR	0	12	24	44	20	3.7	0.92
19. Improve my teamwork experience compared to previous occasions	PL	2	10	30	34	24	3.7	1.01
	IR	2	4	34	50	10	3.6	0.80

(*continued on next page*)

Table 7 (*continued*)

Do you agree that team forming through Belbin's role theory has favoured the following aspects of your team and personal work?	Category[a]	Students' percentage distribution[b]					Mean	SD
		1	2	3	4	5		
20. Improve the motivation level of the group								
21. Improve the level of personal motivation	PL	2	10	24	50	14	3.6	0.91
22. Decision-making at the personal level	PL	2	16	28	44	10	3.4	0.94
23. The organization of my time and tasks	PL	2	16	45	31	6	3.2	0.86

[a] Category (IR: Interpersonal Relationship; PI: Positive Interdependence; IA: Individual Accountability; PL: Personal level.
[b] Likert scale (1 strongly disagree, 2 disagree, 3 neither agree nor disagree, 4 agree, 5 strongly agree)
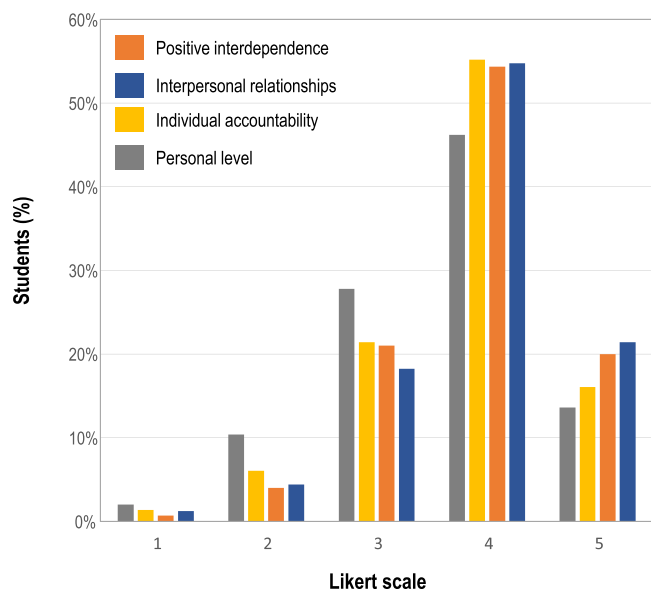
Fig. 11. Students' feedback experience and opinion from Table 7, grouped into four categories: Positive interdependence, Interpersonal relationships, Individual accountability, and Personal level.

#14, #16). Items associated to personal level are the lower rated (#8, #17, #19, #21, #22, #23).

7. Holistic performance in relevant aspects about the intervention of forming Belbin Teams in the Process and Product Engineering course

According to students' opinions, the team forming method on Belbin's role theory helped them and their teams in matters related with positive interdependence, interpersonal relationships and social skills and individual accountability, in this order. The students within Belbin teams (18/19 and 19/20) acknowledge that they attend classes more regularly, they need less time for study outside the classes and their interest for the subject at the end of the course is higher, than the students within self-selected teams. This opinion is coherent with the higher marks scored in the individual exam, IAF factor and project

deliverables.

For our students, PBL methodology is rather new, since the lecture is the most widely used teaching practice among their faculty, while the practice is exclusively based on exercises with only one solution to be solved individually, and with little space for the learning through ill-structured and open-ended problems. When working in teams, generally team forming does not meet compatibility criteria. But the most important fact is that they do not receive instruction or facilitation on essential aspects of teamwork. Hence, teams face the problem in a self-directed way. That is why the instructors observed high satisfaction from students with respect to the team forming process (Fig. 2) and especially with the initial sessions for raising student awareness. We observed that, after filling out the BTRSPI, the students received the report of their Belbin role distribution with much expectation and enthusiasm. We believe that this has been a motivating moment for them, since many students have realized that they have skills that are essential for the team success, even though their marks record in other subjects are average or poor. Proof of this are their reflective essays, such as the one shown in Table 4 (Fig. 2, step 6). 95% of enrolled student submitted these reflective essays.

Many authors in the literature underline the need for instruction on how to work effectively as a team, before placing students into a team; and to ensure they do not develop negative perceptions of teamwork (McGourty and Demeuse, 2001, Barkley et al., 2005; Hilton and Phillips, 2010; Powers, 2020; Smith et al., 2012). Particularly the lecture on Belbin team role theory (Step 4), the completion of the self-perception and observer assessments (Step 2) and their results on Belbin GetSet report (Step 5), followed by the self-reflective essay (Step 6) gave students the opportunity to identify their own strengths and weaknesses. Subsequently, the construction of the Belbin team role circle (Step 7) provides learners with a greater understanding of the roles (behaviours) of individuals within groups and their strengths and weaknesses and encourages learners to focus explicitly on group work skills. Smith et al. (2012) collected some feedback from students who acknowledged it. Table 8 collects some of our student's reflections on their experience of teamwork and the roles they played, extracted from their reflective-essays at the end of the project (step 8). Overall, we believe

Table 8
Some student's reflections on their experience of teamwork and the roles they have played, extracted from their reflective essays at the end of the project (step 8).

"Finally, I have to say that this work has helped me to reflect on the attitude of my teamwork and, in the future, I will try to put into practice my conclusions. I would like to take this opportunity to thank my colleagues at the same time, because although we have had our ups and downs, we have always ended up smiling. Even more so in the hardest moments of the team we have learned to play our roles"

""First of all, in terms of the number of participants, it was a very appropriate size, neither too large nor too small. In addition, I think it is important that as soon as the teams have been built, a first meeting was held to foster relationships with the new colleagues. In principle, you cannot use the same words with new and unfamiliar colleagues as you do with your friends. At this point, acting in different groups makes you say things respectfully and in a good way".

"At first, I did not feel very comfortable because I only knew one colleague. That set me back a bit. I did not have a good feeling about it. As soon as we started working on the milestones, we got to know each other, but the lack of communication quickly became apparent, although that did not negatively affect the milestone grades. It was clear that we were all able to get better marks if we were all interested in it. We had some conflicts in terms of sharing information. We tried to find a solution to this conflict through the right words. After we talked about it and solved the problem, we got even better marks"

"In terms of the Belbin roles assigned to me by my teammates, the role of the Finisher is predominant. I have to admit that it is not my preferred role, but my colleagues are right, because there was no one else who acted as a finisher"

"I have noticed that my strong roles for which I was assigned to this team and the roles I have been playing during the project are different. The role of specialist is the one I have played stronger. I also identify myself quite strongly with the implementer role. The truth is that in this team I have spent a lot of time in organising the work, because otherwise, nobody would take that role and everything would be left to the end"

that this has contributed to fostering psychological safety within the teams, through which engagement to teamwork is promoted (Salas et al., 2018). Ultimately, the learning outcomes associated with teamwork are more effectively approached (Table 2). In contrast to our result and that reported by Smith et al. (2012), McHarg et al. (2012) found no better group functionality among Belbin teams with respect to non-Belbin control groups (randomly assigned). However, they did not provide students with any information or guidance on teamwork under Belbin's approach. Students did not know whether they were assigned to a Belbin group or a control group. Moreover, the group facilitators did not know if they if they were guiding a Belbin group or a control group.

The reflective essays on their role distribution given by the Belbin report, have given us an insight into each of the students, especially in non-academic aspects (interests, skills, part-time working, etc.). Consequently, we have observed that our perception of all students has also changed, from the simplistic perception of "brilliant", "good", "average" and "poor", to the perception that all have positive skills to contribute within teamwork. This has changed our attitude towards them, and of course, they have perceived and appreciated it. This has been reflected in the progressively improved rating in students' assessment of our teaching quality. Of course, the fact that we have gained experience from year to year has also helped.

The whole set of elements has allowed us to increase the level of motivation, engagement and interest towards the subject, and, therefore, the teams' and individuals' performance. However, we found some dysfunctions in few groups, as was the case of a team that was not able to deal with the non-negotiable weaknesses of some members' roles (plant, shaper). Notably that some passive members also produced internal tensions. Nevertheless, compared to previous years, the cases of dysfunctions were less, and moreover, we were able to detect them sooner and give support to the teams. It should be kept in mind that this is the students' first experience with the Belbin methodology. If Belbin's role theory were to be extensively used within the undergraduate programme, and team compositions were different in each learning context (as the team composition choices are diverse to meet a role-based balanced team), this would allow the students to gain experience in modulating their behavioral roles within the different teams. An additional limitation is the lack of time for more group processing sessions (Step 8) during PBL process, since this activity enables members to acknowledge one another their behavioral roles, strengths, weakness and contributions to the teamwork. Due to different reasons (student's lack of experience, lack of confidence, fear, shame), we found it necessary to conduct the group processing in the presence of the instructor for guidance. It takes about 30 min for each group. In our case, as in many other universities, a sole instructor is in charge of 30–35 students; and therefore, some of the meetings need to be scheduled outside class time.

Another issue and limitation that may generate some controversy is the cost of accessing the Belbin Getset platform (property of Belbin Associates) and getting the Belbin report, as well as accessing software licenses for simulation and computation (PRO/II, Aspen Plus, Matlab, etc.). In our opinion this cost is worth it, considering that the ability to communicate and work effectively in a team is one of the skills in greatest demand by engineering companies (Loughry et al., 2014; Oakley et al., 2004; Zhang et al., 2020), and it is also a key outcome required for the accreditation of engineering programs (ABET, 2020, EFCE, 2020). We also subscribe to the view of Smith et al. (2012) that the Belbin scheme is relevant and meaningful to the undergraduate group projects and a useful tool to guide students towards their future employability.

8. Conclusions

This paper shows how an intervention of forming student teams for Project Based Learning through Belbin's role theory has been implemented and the impact of such intervention on the students' performance. The results obtained in the 18/19 and 19/20 academic years

(Belbin teams) have been compared with 16/17 and 17/18 academic years (student self-selected teams).

The methodology proposed for team formation based on Belbin's role theory has been successfully applied, since most of the roles were represented near the 70th percentile, even though not all of them exceeded it. Belbin teams have performed significantly better than self-selected teams, in terms of the scores obtained in both team project and individual exams. IAF scores have also been higher in Belbin teams than in self-selected ones, which could be related to a higher engagement to the team and to the PBL project. According to students' opinion, forming teams according to the Belbin role theory has positively contributed to enhancing the cooperative learning elements, interpersonal relationships and social skills, positive interdependence, and individual accountability, which, in turn, improves team and individual performance. Additional benefits of forming Belbin teams should be highlighted: (1) students are now more aware of the different team and individual skills needed to success within a team; (2) they have shown a greater self-understanding of their strengths (and weaknesses); (3) they have learnt to work in an environment focused on diversity (of roles and skills), rather than on friendship.

Based on students' feedback experience and opinion, both students' interest in the subject and class attendance have notably increased. Moreover, students have stated that they devote less individual study time per week outside the class. All this data confirm the higher effectiveness of the PBL groups built by the Belbin's role theory than by self-selection; and the higher learning achieved within team members.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ece.2021.09.001.

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