# Using the Behavioural Tendency of Students in a Team Environment for Team Formation

Nahia Ugarte[*], Asier Aranzabal[†], Ana Arruarte[‡], Mikel Larrañaga[§],*Member, IEEE*
[*]*Department of Computer Languages and Systems*
*University of the Basque Country UPV/EHU*
nugarte005@ikasle.ehu.es
[†]*Department of Chemical Engineering*
*University of the Basque Country UPV/EHU*
asier.aranzabal@ehu.eus
[‡]*Department of Computer Languages and Systems*
*University of the Basque Country UPV/EHU*
a.arruarte@ehu.eus
[§]*Department of Computer Languages and Systems*
*University of the Basque Country UPV/EHU*
mikel.larranaga@ehu.eus

***Abstract*—The formation of teams of students is a key aspect for the success of group activities in learning environments. The purpose of this work is to design and implement TalSor, a platform that automates the creation of efficient teams of students using Artificial Intelligence techniques. TalSor uses genetic algorithms to build efficient and well-balanced student teams considering the *Behavioural tendency in a team environment* criterion. The tool, which allows instructors to set the number and/or size of the teams, uses the Belbin Team Role Self-Perception Inventory to determine the behavioural tendency of the students and to create heterogeneous teams of students. In addition, and taking into account that there are areas, such as engineering education, in which the gender divide is more evident, TalSor aims to seek balanced teams also in terms of gender. TalSor has been tested in the subject *Process and Product Engineering* of the Chemical Engineering Degree in the University of the Basque Country UPV/EHU obtaining quite satisfactory results.**

***Index Terms*—team formation, team-based learning, behavioural tendency in team environments, genetic algorithm**

## I. Introduction

In current educational trends, practically at all levels of formal education (primary, secondary and university education) and at all educational disciplines (theoretical areas, areas of science, language learning…), teachers and students work together to construct knowledge. The role of teachers has evolved to become designers of experiences and active environments. Most active learning procedures are based on cooperative learning, which requires students to work together in small teams maximizing their own and their peers' learning [1]. Numerous studies highlight the benefits of Team-Based Learning in Project-Based Learning scenarios, which has been shown to be appropriate for developing, among others, problem-solving skills, interpersonal team skills, and communication and behavioral skills [2], [3]. Some studies acknowledge that students who learned in a team or by observing a team performed better than students who learned individually [4].

The formation of work teams is a key aspect for the success of group activities. A good configuration of student groups produces better results, and higher performance can be achieved if the appropriate criteria are used when defining the teams. Some studies discuss strategies to create good teams and improve their effectiveness [5], [6]. However, the creation of effective teams of students is a hard task. Instructors and teachers usually do not have the appropriate criteria and tools to define the teams or they do not have the information which is required to form the teams in an optimal way.

In the reviewed literature, several tools or software to create groups based on different criteria can be found. For example, CATME [7] collects the information given by the teachers and allows them to generate the teams according to the desired criteria: Grade Point Average, experience in previous courses, age, etc. Unlike CATME, the RAMSET tool [8] uses other techniques such as sociograms or personality tests (e.g., Jung [9], Keirsey [10]) in order to collect the data. Once the data is collected, it correlates the personality traits to the role within the team and generates the groups. In our work, contextualized in the educational field, we do not consider personality tests, because sometimes the items that appear refer to situations that the students have not had the opportunity to experience, and for this reason we use the Belbin model [11], which identifies the roles natural of the students.

The final purpose of our work is also to facilitate teachers and instructors in the creation of efficient teams of students. With this aim, the development of a platform that automates the creation of efficient and well-balanced teams of students using Artificial Intelligence techniques has been dealt with, specifically, TalSor, a tool that uses genetic algorithms to build efficient and well-balanced student teams considering both the *Behavioural tendency in a team environment* of the students and their gender. TalSor, which allows instructors to set the number and/or size of the teams, uses the Belbin Team Role Self- Perception Inventory to determine the behavioural tendency of the students and to create heterogeneous and role-balanced teams of students. The proposal has been tested in the subject *Process and Product Engineering* of the Chemical Engineering Degree in the University of the Basque Country UPV/EHU, obtaining quite satisfactory results.

The paper is structured as follow. Section II presents a summary of the literature review carried out on the construction of efficient teams of students. Section III describes TalSor, a tool for the formation of effective teams of students based on the *Behavioural Tendency in a Team Environment* of the students. Section IV presents the experiment in which TalSor was used and evaluated. Finally, Section V presents the conclusions and future work.

## II. A LITERATURE REVIEW ON THE CONSTRUCTION OF EFFICIENT TEAMS OF STUDENTS

This section reviews some aspects that should be taken into account when generating efficient and well-balanced groups of students.

### A. Information required for building efficient teams

As pointed out above, teamwork is one of the most relevant professional skills and many of the educational methodologies which are more frequently being used nowadays highly rely on effective teaming skills. A literature review has been conducted to identify the type of information about the students that is necessary to form efficient teams of students. The review identifies as relevant criteria:

1) **Personality style**: It refers to elements of personality, including attitudes, modes of thought, feeling, impulses, strivings, actions, responses to opportunity and stress and everyday modes of interacting with others, expressed in a characteristically repeated and dynamic combination [12]. Personality influences the cohesion of the team, how the members solve their conflicts and, consequently, the effectiveness of the team [8].
2) **Social relationships**: Using data about the social relationships of the members allows teams to be formed which are composed of members with a high degree of affinity. This can prevent problematic situations, and therefore the work can be more fluid and effective [8].
3) **Learning styles**: Learning styles refers to the various techniques that students prefer to use to perceive and process information and interact with the learning environment [13]. These criteria have become common for creating groups of students and make them function effectively in a collaborative environment [14].
4) **Behavioural tendency in a team environment**: This is related to how an individual behaves in a team environment, i.e., the role. A role is "a tendency to behave, contribute and interrelate with others in a particular way" [11].

Despite being used with less frequency, there is other information that might be relevant when creating teams of students: skills and abilities, previous works, knowledge and academic data, the opinions of the students and feedback, preferences and interests, and demographic data.

The literature review has shown that the *Behavioural tendency in a team environment* is a criterion experiencing an increasing interest in higher education, especially among science and engineering instructors [15]–[22]. Specifically, Belbin role theory [11] is accepted worldwide, especially in the professional fields of counseling, development and management. The role describes how someone behaves and interacts with the others, independently of their functions within the group. Group roles are not necessarily static, and people may adopt different roles at different times during the group's life-cycle. A group composed of students with complementary profiles provides a good teamwork performance [23], which positively impacts the results of the students [24], [25].

The Belbin Team Role Self-Perception Inventory (BTRSPI) test was designed to measure behavioural characteristics that individuals display when working in a team [11]. It identifies nine behaviour patterns (i.e., roles): plants, resource investigators, coordinators, shapers, monitors, team workers, implementers, finishers, and specialists. The roles should be played by the different team members in order to facilitate successful teamwork. When completing the BTRSPI test, candidates are asked to distribute ten marks in each section of the inventory. In Engineering Education, Belbin's roles have been used to manually form balanced teams with the aim of boosting positive interdependence and individual accountability within the teams and improving their performance in a project-based learning environment [26].

### B. Type and size of the group

Once the criteria and the instruments that can be used to collect the required information have been collected, new questions about the setup of the teams arise. How should the teams be? Should the teams be homogeneous or heterogeneous? How many members should the teams have? Teams can be created joining members who have similar characteristics, namely homogeneous teams, or joining members who have complementary characteristics, that is, heterogeneous teams. In homogeneous teams, the similarity between members can aim for fewer conflicts and better understanding, but, in some cases, members may have difficulties in carrying out the work, since certain characteristics will not be reflected in the team. However, in heterogeneous teams, the diversity among the members can make them complement each other and perform better.

According to the review conducted, there is more research which bills heterogeneous teams than works that promote homogeneous teams. The results of the studies suggest that diversity is highly correlated with success [27] and may provide greater motivation and benefit [28]. In the case of *Behavioural tendency in a team environment*, Belbin defends that a team showing a balanced representation of all the nine team roles will have a grater propensity to perform highly [11]. There are studies that defend that the similarity of some characteristics between the members of the team leads to a more uniform participation and immediate productivity [29].

The *size of a team* is also an aspect that must be considered when creating a team. The size of a team is something that varies according to the objectives or the type of work to be done. Teams that are too small may not have sufficient resources to achieve the pursued work, and teams that are too large may have communication problems or be less productive [25]. Gaviola et al. [30] pointed out that the best size is the one that allows the participation of all members.

### C. Additional aspects: Gender

The area of engineering education has not been an exception in the incorporation of learning disciplines that require team working and there are many authors who, during the last few years, claim the need to emphasize the importance of collaborative teaching strategies in the development of future engineers [31]. However, in this area, as in most areas related to STEM education, there is an additional aspect that we believe should be considered when creating teams of students: *gender*.

When creating teams, one potentially important dimension of heterogeneity is gender [32]. It seems that gender plays a potentially important role in social interaction among group members [33]. There are studies that suggest that "*students in gender-balanced groups display enhanced collaboration in group work processes associated with less social loafing behaviours and more equitable contributions to the group work*" [34].

## III. TalSor: a Tool for Team Formation Based on Student's Behavioural Tendency

Team Formation, i.e., the definition of effective teams, is crucial for team-based learning. Although it may be argued that working in teams which are not that effective might prepare students for their "real working life", we think that in educational contexts, the learning process of those students who work in ineffective teams might be compromised. Given the relevance of this task, a lot of research is being conducted to optimize the team formation in learning and working scenarios.

As teachers and researchers in the area of Technologically Supported Learning Systems, we consider the creation of a tool that automatizes the creation of teams for learning scenarios essential. Throughout this section, the design objectives and the main features of TalSor, a tool for building Teams in Team-Based Learning scenarios, is presented.

As the literature review concluded that heterogeneous teams, formed by members with complementary characteristics, are more desirable, TalSor will generate this kind of teams. In addition, TalSor will seek to promote parity regarding gender, trying to build teams with an equal or similar number of male and female members. As there is no consensus about the ideal number of team members, except that the number of members must not hamper the communication, TalSor will not impose any restrictions in this regard. It will allow the instructors to determine either the number of team members, or the number of teams to be generated. In the latter case, the number of members per team will be automatically inferred.

With regards to the criteria used to build the teams, the *Behavioural tendency in a team environment* approach was adopted taking into account the needs of the subject *Process and Product Engineering*, in which students are trained in a Project Based Learning environment. The instructors of the subject interviewed former students and asked them to reflect, based on their experience, upon the type of skills that team members should bring to the team to successfully complete the project. Teachers found out that most of the suggested competencies and duties were not strictly based on technical skills and knowledge, but on professional skills, which are closely related to those referred by behavioural tendency, such as Belbin's roles [26]. Therefore, the *Behavioural tendency in a team environment* was considered as the appropriate team forming criteria, as the other alternatives do not consider professional skills. The Belbin Team Role Self-Perception Inventory (BTRSPI) test was chosen as the means to elicit the required information.

In order to assure that all the students can profit from the Team Based learning process, the teams should be well-balanced in two ways. On the one hand, the members should present complementary profiles, so that all the Belbin roles are "covered". On the other hand, all the teams should have similar capacities; otherwise, the learning process of some teams might be compromised. In addition, teams should have a similar number of members. When the number of students ($M$) is not multiple of the number of teams ($G$), TalSor will try to balance the number of members. It will determine the minimum number of team members $M$ using Eq. 1 and only admit one additional member per team.

$$N = floor\left(\frac{M}{G}\right) \tag{1}$$

Fig. 1 illustrates the team formation process using TalSor, which gets the student's Belbin roles and their gender as input and, after processing a genetic algorithm, produces the set of effective and well-balanced teams of students.

Next, the details of the proposed genetic algorithm are depicted.

### A. Details of the genetic algorithm

A genetic algorithm is a kind of evolutionary algorithm aimed at solving optimization problems. In particular, it is a model or abstraction of biological evolution based on Charles Darwin's theory of natural selection [35]. Genetic algorithms mimic the evolution of living organisms, with each generation adapting to its environment.

Genetic algorithms look for a solution in an iterative process where an initial population, which represents plausible solutions for the problem being solved, is evolved through several generations. At each generation, individuals reproduce,

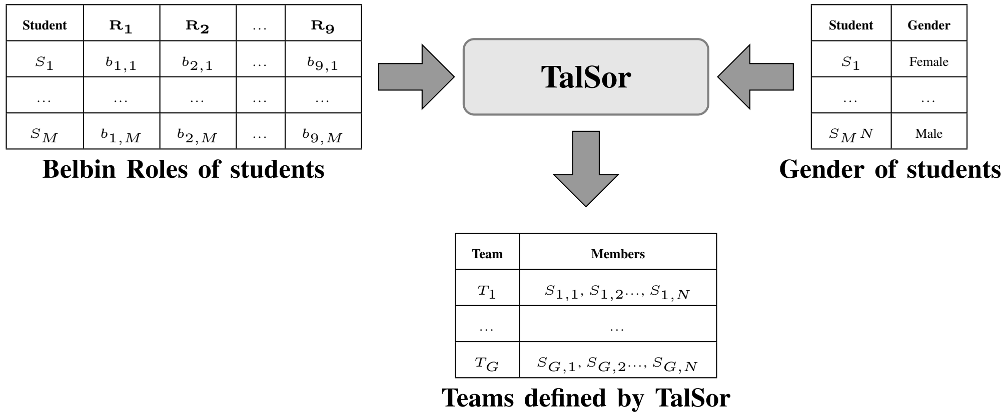


Fig. 1. Team Formation using Belbin Roles and Gender with TalSor

from parents, mixing genetic information. Individuals that fit better to the environment are more probable to be chosen for reproduction. In addition, offspring individuals may eventually suffer slight mutations, that might lead them to better adapt to the environment. Therefore, the genetic algorithms implement the following life cycle:

1) Create an initial random population of potential solutions.
2) Determine how good each individual or solution is.
3) Select pairs of individuals that will reproduce new individuals.
4) Create offspring individuals by combining the genetic information of their parents.
5) Select individuals (considering parents and offspring) that will survive to the next generation.

Steps 2) to 5) are repeated for a predefined number of generations.

When using genetic algorithms to solve optimizations problems, determining how the individuals are represented, how their genetic information is combined, how mutation performs and, how the *goodness* of the individuals is measured are crucial. The following subsections describe how these factors are addressed in our proposal.

*1) Individual representation:* In genetic algorithms, each individual represents a plausible solution for the problem, and each individual is represented by its *chromosome* (genetic code). A *chromosome* is made up of *genes*. A *gene* represents the logical type for the unit, whereas the *allele* is the actual value in the unit.

In this work, each individual represents a plausible grouping for students (Fig. 2). The *chromosome* has $N$ *genes*, where $N$ is the number of students that are being distributed in different teams. Each *gene* represents the team the corresponding student belongs to. It can take values from $1$ to $G$, where $G$ represents the number of teams being defined.

The population contains different individuals, each of which represents a different grouping. For instance, in Fig. 2, the first individual states that $student_1$ belongs to $team_2$, $student_2$ is a member of $team_1$, $student_3$ is part of $team_G$ and $student_M$ belongs to $team_3$.

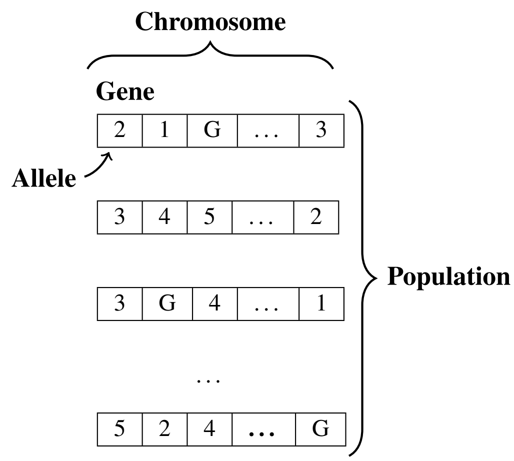


Fig. 2. Example of a population in TalSor

*2) Initial population generation:* The initial population is made up of randomly generated individuals. As mentioned above, each individual's *chromosome* has $M$ genes, each specifying the team for the corresponding student. To create each individual, the values for the *alleles* are generated and saved in a list. As each team must have at least $N$ members, each team is appended $N$ times in the list. If $M$ is not multiple of the number of groups ($G$), random teams are appended for each "missing" student. Once the list contains $M$ values, the list is shuffled to obtain the *chromosome* of the individual.

*3) Crossover:* The crossover function determines how the genetic information of the parents is combined in the offspring individuals. There are several strategies for crossover. In this work, a single-point crossover approach (Fig. 3) was adopted. The *chromosomes* of the parents are split into two parts, which are combined in the offspring individuals (taking one part of each parent).

*4) Mutation:* The mutation may produce slight changes in the *chromosomes* of offspring individuals, encouraging diversity in the population, and eventually improving the

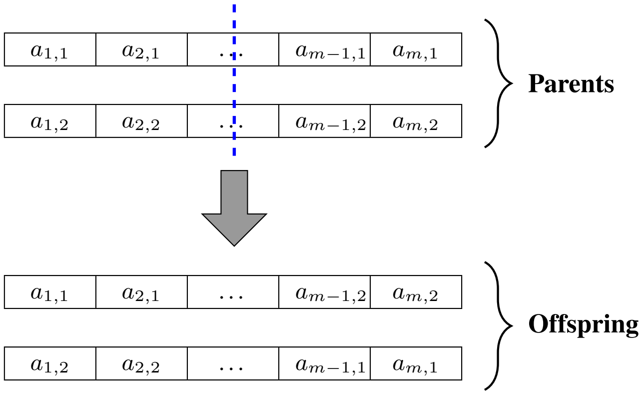


Fig. 3. Offspring generation through crossover

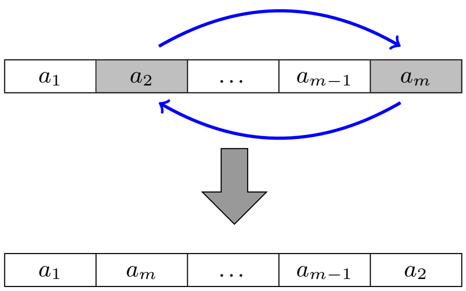


Fig. 4. Mutation of a offspring individual

adaptation of the individuals to the environment, i.e., making the individual represent a better solution for the problem being solved.

The mutation operation depends on the encoding of the *chromosomes*. There are several strategies to carry out mutation, from changing one of the *genes* to swapping two randomly selected *genes*.

Randomly modifying one of the *alleles* may increase the risk of producing invalid groupings, as there could be teams with too many students or less than the required number of students. To minimize this risk, the mutation strategy implemented in this work entails swapping the *alleles* of two randomly selected *genes* (Fig. 4).

*5) Fitness function:* The *fitness* functions measures how good an individual adapts to the environment, i.e., how good the solution is for the problem.

The *fitness* function implemented in this work to optimize the team formation process carries out several actions. First, considering the *chromosome* of the individual and the input data, i.e., the matrix that represents the Students' Belbin Roles and the matrix that represents the students' genders, a matrix that comprises the Belbin Roles of the team students and a vector that represents the gender of the team students are generated for each team (Fig. 5). Next, these matrices and vectors are processed to compute the score of each team ($r_j$), as described in Fig. 6. To this end, the team Belbin Role vector ($\vec{b}_j$) is computed for each vector. These vectors contain the average Belbin Role values of the team members for each Belbin Role ($\bar{b}_{i,j}$, which are computed using Eg. 2).

$$\bar{b}_{i,j} = \frac{1}{N_j} \sum_{k=1}^{N} b_{i,k} \tag{2}$$

Using Eq. 3, the vectors are them processed to compute the Belbin score ($\bar{b}_j$) for each team.

$$\bar{b}_j = \frac{1}{9} \sum_{i=1}^{9} \bar{b}_{i,j} \tag{3}$$

With the aim of promoting gender parity in the teams, the gender score ($g_j$) is computed for each team from their corresponding Team Gender Vector. To this end, Eq. 4, which measures the balance between male and female team members, is used.

$$g_j = 1 - \left( \frac{|f_j - m_j|}{N_j} \right) \tag{4}$$

The score of each team ($r_j$) is then computed using Eq. 5. The score of the team is obtained by summing the gender score, multiplied by $\alpha$, a weight factor that determines how much the gender should be considered, to the Belbin score, and dividing the result by $1 + \alpha$.

$$r_j = \frac{\bar{b}_j (1 + \alpha \ g_j)}{1 + \alpha} \tag{5}$$

Finally, the *fitness* of the individual is computed applying Eq. 6. If there is any invalid team, the equation will assign 0 *fitness* to the individual. A team is considered invalid if it has a wrong number of members (too many or fewer than necessary members) or unbalanced roles, i.e., any of the $\bar{b}i, j$ values is over 70, which may indicate that this role is over-represented.

$$fitness = \begin{cases} \dfrac{\bar{r}}{\sigma_r} & \text{if all teams valid} \\ \\ 0 & \text{otherwise} \end{cases} \tag{6}$$

If all the teams are valid, the *fitness* is computed by dividing the average team rating ($\bar{r}_j$) by the standard deviation of the team ratings ($\sigma_r$), which are computed using Eq. 7 and Eq. 8 respectively.

$$\bar{r} = \frac{1}{G} \sum_{j=1}^{G} r_j \tag{7}$$

$$\sigma_r = \sqrt{\frac{1}{G} \sum_{j=1}^{G} (r_j - \bar{r})^2} \tag{8}$$

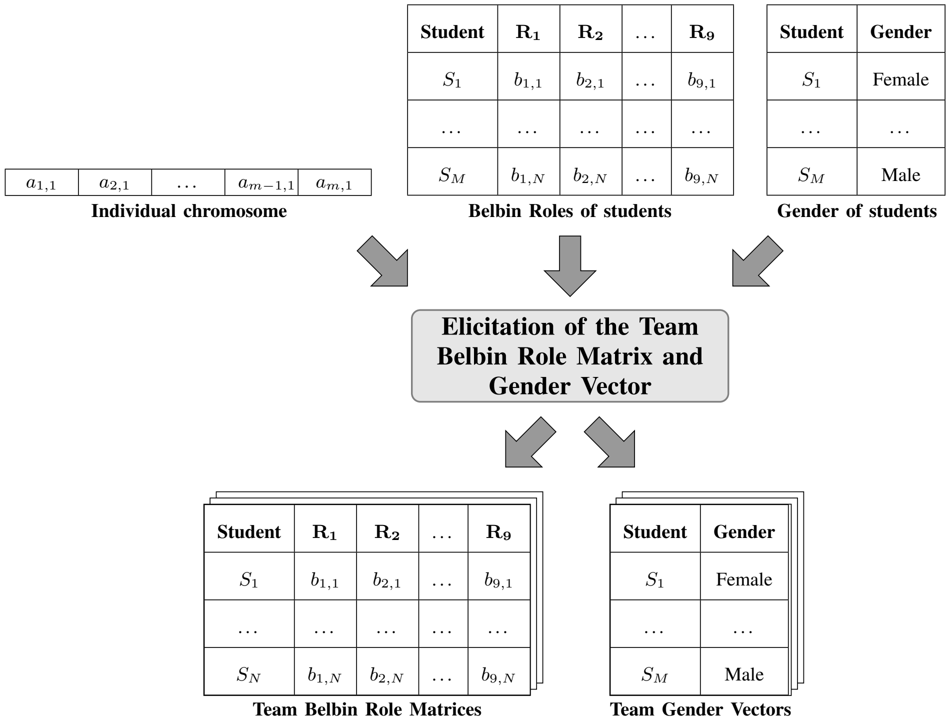


Fig. 5. Generation of the Belbin Role matrices and Gender vectors for each team

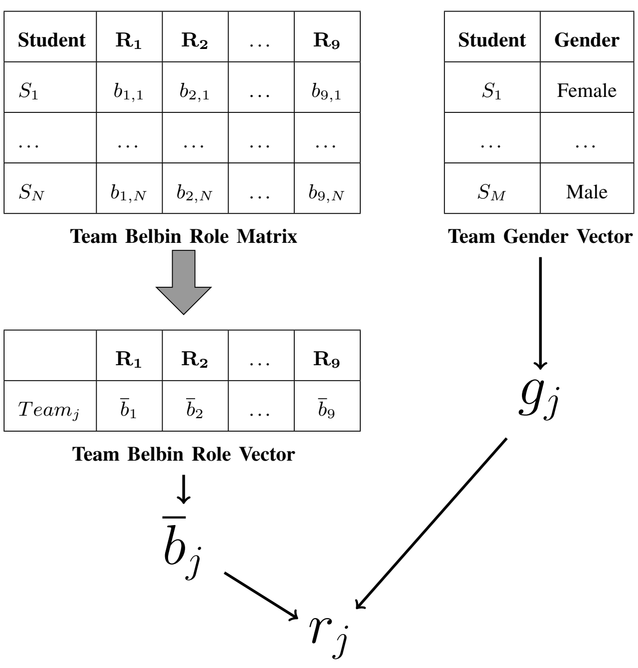


Fig. 6. Computing the score of an individual

## IV. Experiment and evaluation

TalSor has been tested in the subject *Process and Product Engineering* of the *Chemical Engineering Degree* at the University of the Basque Country UPV/EHU. It is a compulsory subject (9 ECTS credits) in the 5th and 6th semester, i.e., the first and second semester of the third year of the degree. In the first block (4.5 ECTS, 5th semester), where the principles of analysis, synthesis and design of chemical processes [36], [37] are covered, Project-Based Learning (PBL) is the core teaching-learning methodology. Students teams, made up of 4-5 members, are asked to develop a base-case design project of an industrial chemical process, including its economic and profitability analysis, i.e., dimethyl ether production from methanol, production of benzene from shale gas, production of ethylbenzene, and so on [26]. The number of students enrolled in the 2021-2022 academic year was 32.

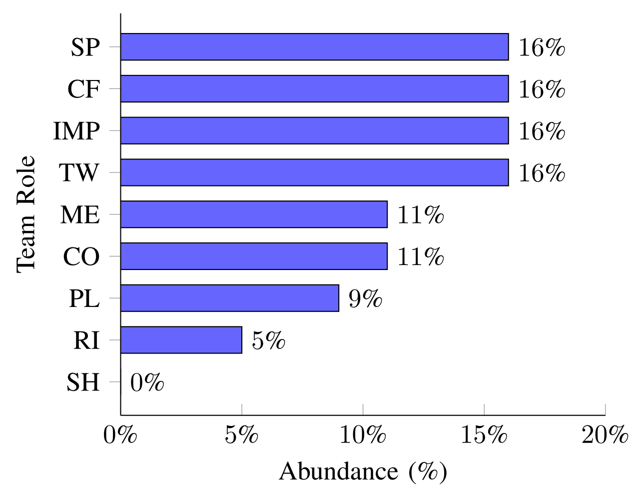


Fig. 7. Overall distribution of the two strongest Belbin roles

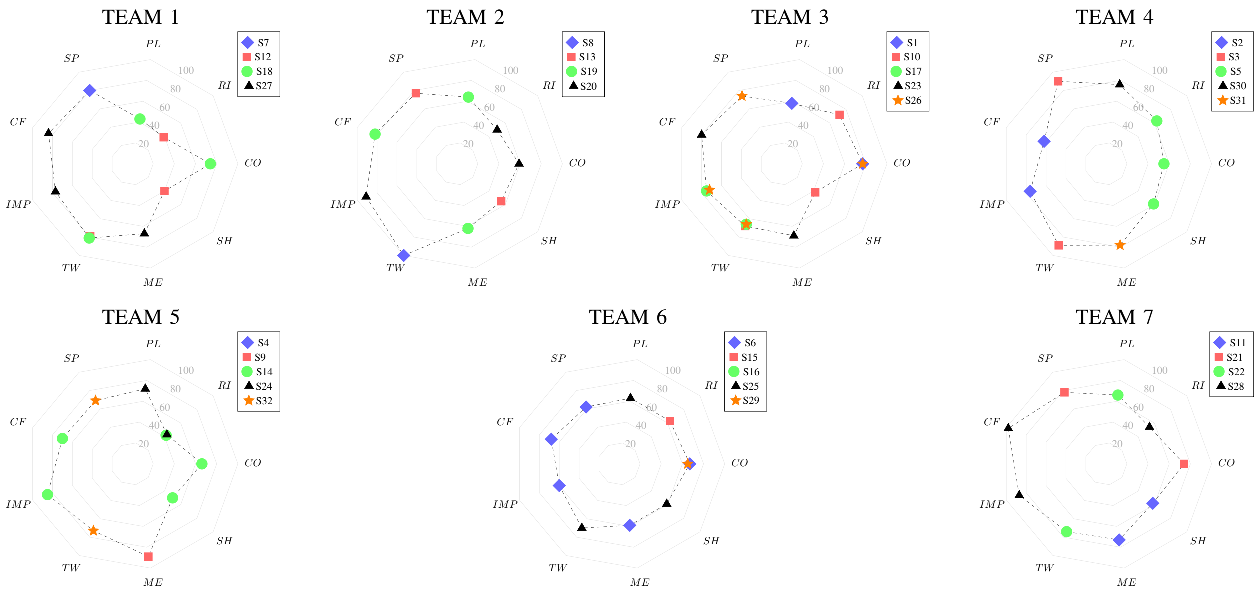


Fig. 8. Role distribution per team in Experiment 1

Students were asked to complete the Belbin Team Role Self-Perception Inventory (BTRSPI), provided by Belbin GETSET, which was combined with the Belbin's Observer's Assessment Sheet (OAS) to get the Belbin reports. It makes 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".

Team formation is strongly influenced by the characteristics of the people being organized into teams and the roles those people can take on by working in the teams. In this regard, an analysis of the Belbin roles of the students was conducted in order to identify the two strongest Belbin roles of each student,. i.e., the roles in which each student had higher scores. According to Belbin's basic concept [38], a team is balanced if each role is represented in at least one team member's first or second highest scoring role.

Fig. 7 shows the obtained overall distribution of the strongest Belbin roles of the 32 students enrolled in the subject. The most present roles are *Specialist* (SP) (16%), *Completer/Finisher* (CF) (16%), *Implementer* (IMP) (16%) and *Teamworker* (TW)(16%), while the less common roles are *Shaper* (SH) (0%), *Recourse Investigator* (RI) (5%) and *Plant* (PL) (9%). In addition, 11% of the students had either *Coordinator* (CO) or *Monitor Evaluator* (ME) as one of their strongest roles. This analysis shows that the rather low number of students (32) and the heterogeneous distribution of the strongest roles are a limiting factor for a fully balanced distribution of Belbin roles. The gender distribution can often be another limiting factor, but in this case the number of women and men was the same (16+16).

In order to evaluate TalSor, two experiments were conducted. Experiment 1 only considered the Belbin roles ($\alpha = 0$), whereas Experiment 2, in addition to the Belbin roles, also considered the gender ($\alpha = 0.3$), to observe how gender affects the team formation process.

In both experiments, the students were distributed into groups of 4 and 5 members. The data corresponding to Experiment 1 shows that TalSor was able to create well-balanced teams of students ($\sigma_r = 0.497$). Furthermore, it ensured the presence of at least one student whose main role is the least abundant (RI, PL) in each group. However, this best combination allows some roles to be represented twice (teams 1, 4, 5 and 6), especially the most abundant roles (Fig. 8). Most of the roles are represented near the 70th percentile, even though not all of them exceed it. This condition is difficult to meet, due to the limited number of students and the heterogeneous distribution of the strongest roles, as stated before.

Fig. 9 shows the role profiles of the 7 groups generated in Experiment 2. The coloured dots represent each student's score in their two strongest roles, while the dotted line indicates the group's highest score in each of the roles. Again, most of the roles are represented near the 70th percentile. Fig. 9 shows that the teams are better balanced in behavioural tendency ($\sigma_r = 0.054$). The role distribution represented in Fig. 8 and Fig. 9 meet the criterion specified in [38], so all of them are balanced.

The opinion of the actors involved in any learning activity, i.e., the instructors and the students, must be considered when evaluating any pedagogical innovation. According to the *Process and Product Engineering* instructors, the team compositions shown in Fig. 8 and Fig. 9 allow student teams to perform significantly better than when students form the team by themselves. In previous experiences using Team-Based Learning in Project-Based Learning scenarios [26], in which the instructors defined the teams of students considering

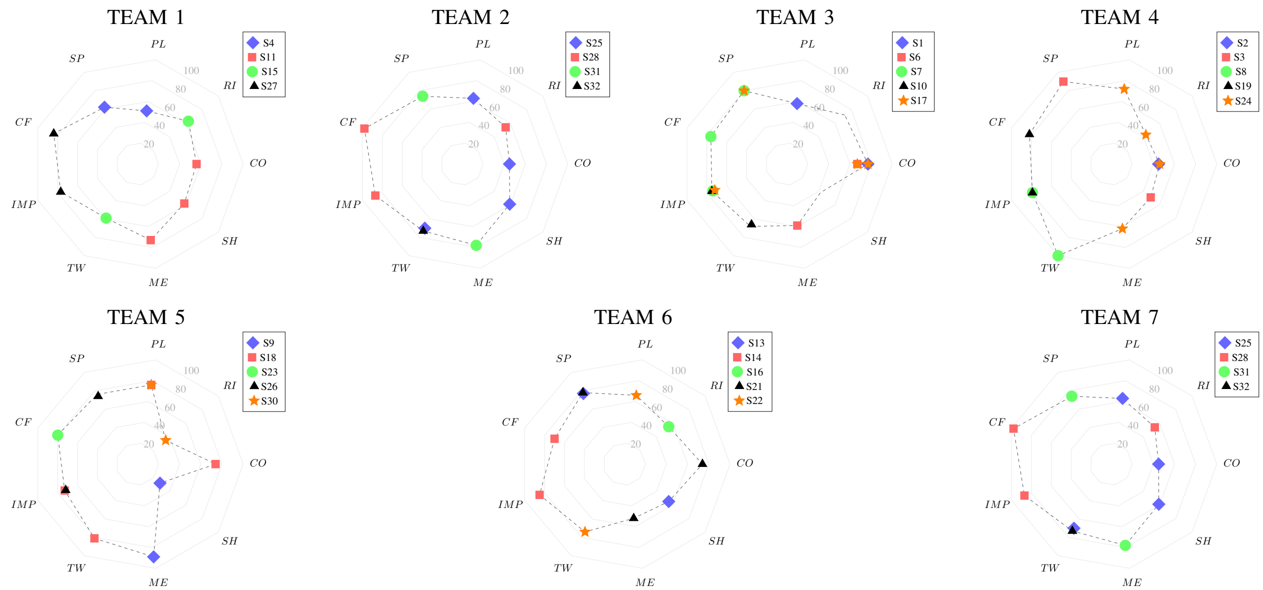


Fig. 9. Role distribution per team in Experiment 2

the Behavioural tendency in a team environment of the student, a better performance was concluded in terms of the scores obtained in both the team project and individual exams.

Regarding the opinion of the students, balanced teams in behavioural tendency positively contributes to enhance the cooperative learning elements, interpersonal relationships and social skills, positive interdependence, and individual accountability.

## V. Conclusions and Future Work

In this work, we present TalSor, a tool that uses genetic algorithms to build efficient and well-balanced students' teams considering the *Behavioural tendency in a team environment* of the students. Other alternatives in the literature rely on academic data or personality tests to create teams of students. However, personality tests might not be the best approach for educational environments, as many test items usually refer to situations that the students, being young, might never have had the opportunity to experience. Our proposal considers the professional skills that the students contribute to the team.

In addition to the Behavioural tendency of the students, TalSor also considers the gender dimension of the team members when creating teams of students. Creating gender-balanced teams, especially in areas such as engineering or STEM education, where males are the predominant gender, or sanitary education, where females are predominant, is a relevant issue that should not be ignored.

Although the tool has only been tested in a single real educational context at university level, the results obtained show that the teams of students created both using the behavioral tendency in a team environment of the students as the sole criterion (Experiment 1) and the combination of this criterion together with gender (Experiment 2) provides satisfactory results. In both cases, the generated teams of students are well-balanced.

In the near future, the tool will be evaluated in more real educational settings. However, to evaluate the tool at educational levels lower than secondary education, it is essential to use an alternative to the Belbin Team Role Self-Perception Inventory used to determine the behavioral tendency of the students which is better suited for younger people, since the current test is focused on a population over 16 years of age.

In addition, and thanks to the modular design of the tool, it will be easy to incorporate additional criteria to take into account when creating teams of students. Thus, criteria such as social relationships or learning styles will be easily incorporated.

Another open research line seeks to enhance TalSor with a module able to generate explanations for teachers, and also for students, about the reasons followed to generate the proposed teams, that is, incorporate TalSor with explainability capacity, describing why the teams were made up by those students.

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