e-ISSN: 2250-0758 | p-ISSN: 2394-6962
Volume-11, Issue-6 (December 2021)
https://doi.org/10.31033/ijemr.11.6.10

Development of a Tool for Team Formation in Engineering Education

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ABSTRACT

Efficient team formation presents challenges both for the industry and the academia, especially among first year students. In academia, the difficulty is due to a lack of familiarity between instructors and new students at the beginning of each semester while in the industry, the issue is the incomplete picture of new employee's personality by the supervisors. The quality of the team greatly affects both the team member experience as well as the outcome of assigned projects. There is a strong need to create a tool or a program that allows instructors and supervisors to create effective teams with evenly distributed skills amongst the teams in a timely fashion. Studies show that the balance of skills, rather than the presence of highly skilled individuals, leads to successful teams. The ultimate goal is to create a tool that will give teams the opportunity to operate at their maximum potential.

This paper focuses on the creation of teams for first year students of engineering. The outcome is based on the results of a project assigned to a team of second year engineering students. The choice of second year students was dictated by the need to have students who had already experienced the adverse effects of malfunctioning teams during their previous projects. The goal of the project was to design a software and user interface for a tool that instructors could use to create optimal project teams in an efficient manner.

Keywords-- Team, Formation, Project, Engineering, Optimization, Matlab

I. INTRODUCTION

Teams play a key role in the success of organizations and teamwork is a core competency in higher education. Team performance is often affected by unevenly distributed skill sets along with clashing personalities. The quality of the team greatly affects a student's experience in classes. Time constraints in a semester is an additional hurdle faced by professors in their efforts to create optimum teams. Currently the professors are creating the best possible questionnaire, which is given to the students to understand their specific skills and dominant personality traits.

The survey that is provided does not allow the professor to develop a solid understanding of each individual student. In addition, the professor is forced to manually look at the surveys and do their best to put people together that will work well. This is not the most effective way to create optimal teams and is very time demanding for the professors. There is a need for a tool or a program that can create effective teams with skills evenly spread out amongst the teams. The goal is to design a program that minimizes the time required for professors to assemble teams, as well as create teams that establish the best opportunity for success.

Research has been conducted conducted to learn ideas on what types of skills are the most valuable to the success of a team [3]. Additionally, extensive inquiry on the effects of various personalities within a team was analyzed. This includes an investigation on which personalities or styles complement one another and what kinds clash together. The goal is to ensure that every team has an optimal quantity of the necessary skills and complementary personalities to be effective [1].

As stated by the Mind Tools Editorial Team, people often take on distinct roles and behaviors when working in a group [3]. Teams that exhibit a positive dynamic trust one another and work towards a collective decision while holding each other accountable. The key to achieving positive group dynamics within a team is to proficiently define roles and responsibilities. To attain ideal team dynamics, teams must display competency in a variety of capacities. Teams that exhibit versatility, communication, and creativity are predisposed to higher success.

Francesca Gino described the differences between introverts and extroverts and the effects these personality types may have on a group [4]. Extroverted team leaders can be highly effective by bringing vision with assertiveness, energy, and a strong sense of direction to the group but are more likely to feel threatened by proactive team members. Introverted leaders, on the other hand, are comfortable listening and carefully considering suggestions from their teammates. The outcome of these findings is something known as dominance complementarity. This is the tendency of groups to be more cohesive and productive when they have a balance of dominant and submissive members.

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According to Charles Duhigg of the New York Times, Google, one of the most publicized supporters of studying workers' productivity, began an initiative in 2012 to discover how to develop the perfect team [2]. This project was known as Project Aristotle. Google found that the best teams were composed of those who simply meshed into the most cohesive unit. The only thing that truly made a significant impact on overall team productivity was something known as the group norms. Group norms are the traditions, behavioral standards, and unwritten rules that govern how people function within a team. While team members may behave in a certain way as individuals, group norms take precedence in the team setting and cause them to defer to the team culture. At the end of the day, Project Aristotle researchers determined that what mattered most within successful teams was establishing psychological safety. Psychological safety is a sense of confidence that the team will not embarrass, reject, or punish someone for speaking their honest opinion. Emphasizing that in the best teams, members listen to one another and show sensitivity to feelings and needs early within the team building process may be the most effective way to establish positive group norms.

II. TEAM FORMATION PROCESS

2.1 Team Dynamics Analysis

Team dynamics analysis is conducted to determine which categories are the most prominent as well as what other factors may influence the productivity of a team.

The purpose of the analysis is to determine what makes certain teams perform extraordinarily well while others achieve suboptimal results. Optimizing team dynamics and performance is the ultimate goal of the software developed.

Every team consists of five members with distinctive skills and personalities that serve a unique role within the group. These skills are broken down into five main categories that contain subcategories to further describe each individual's personality or style. The five main categories include leader, creative/artistic, hands on, technologist, and communicator [1]. As determined by the team dynamics analysis, various skill sets must be represented within a collection of individuals that share complementary personality types for the team to be predisposed to a higher level of success. Each team member must contribute an equal amount to increase group's collective intelligence. Engaging in conversations led by professors or team leaders that build connections between teammates induces psychological safety and is the best way to establish positive group norms. Teams that are composed to satisfy all of these criteria will experience the best team dynamics.

2.2 Statements

This section provides information about the statements presented to the students in the introduction during the survey. The statements displayed provide the data that will be entered in the algorithm. The statements are based on a 1-5 scale with 5 representing strongly agree and a 1 representing strongly disagree. The statements are presented in a way that enables the program to collect the necessary data from the students with minimum biased answers.

The purpose of the statements is to understand which students fall into which categories. In order to have strong team dynamics, the statements also are designed to incorporate the learning style of each student in that category which include general, serious and casual. After the statements are answered splitting students into their appropriate categories, some general statements will be presented to get an understanding of what type of groups the students prefer to work in. The research for the statements led to the five categories listed earlier and the leader, the creative/artist, the hands-on worker, a technology expert, and a communicator/scribe.

A key strategy for the outcome to be successful is for the questions to be answered honestly. In order to make the answers unbiased, the questions are created in the form of simple statements that enable the teacher to learn more about each student. Figure 1 shows a capture of questions posed to students and Table 1 presents a color-coded list of the questions. Each color is targeting one of the titles that the students could receive. When the questions are presented to the students, the order of the questions will be randomized. Another feature offered by Table 1 is a description of what type of learning style a student is based on, which statement they most strongly agree with. Since some of the learning styles may overlap among the statements three additional statements have been added at the end of the survey.

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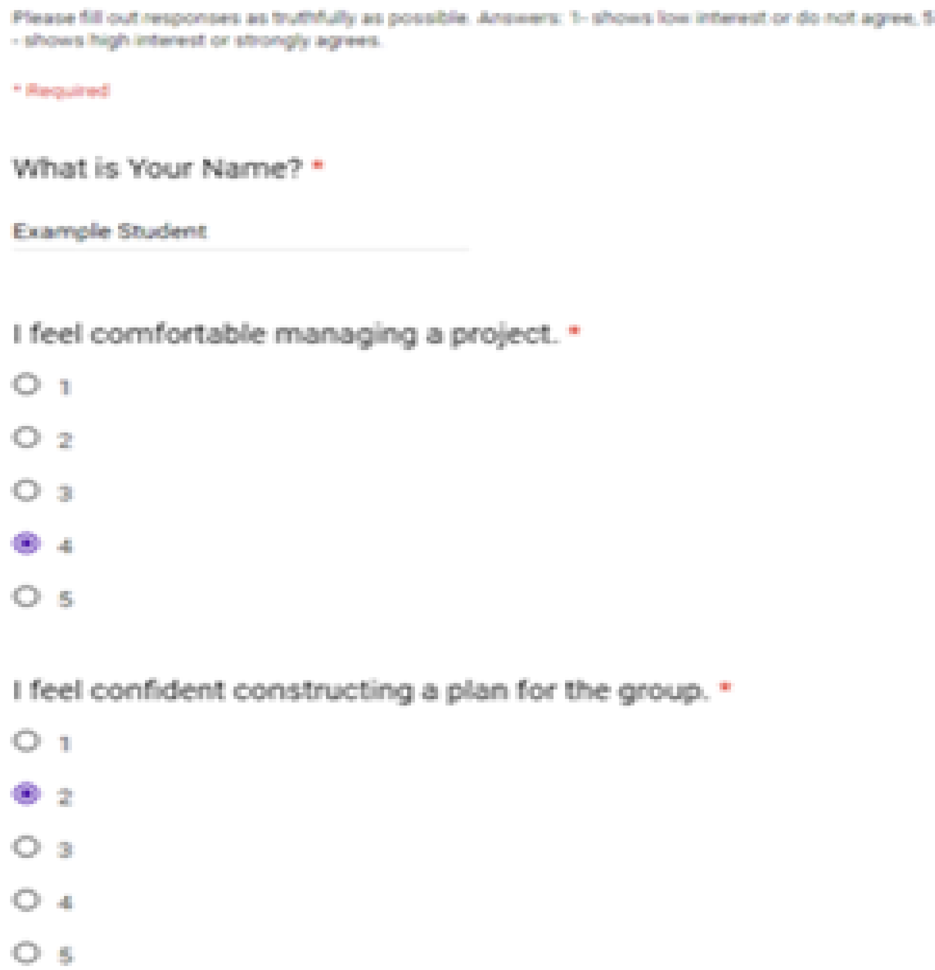

Figure 1: Screen shot of questions presented to a student

Table 1: Statements and corresponding learning styles

Statement Number	Statement	Learning Style
1	I feel confident constructing a plan for the group	Serious
2	I feel comfortable managing a project	General
3	I enjoy having my ideas criticized	Casual
4	I love to sketch, but everything must be neat	Serious
5	I enjoy coming up with creative ideas	General
6	I’m driven by art and enjoy trying new approaches	Casual
7	When building prototype, all dimensions and angles must be exact	Serious
8	I learn the best by using my hands	General
9	I enjoy helping other people construct models	Casual
10	I’m impatient when people struggle with computers	Serious
11	I prefer to work on a computer than in the field	General
12	I enjoy embracing new challenges with technology	Casual
13	I prefer to do most of the group speaking	Serious
14	public communications are not an issue for me	General
15	I like to use my communication skills to learn more from my peers	Casual

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The results from the question survey presented in the Google Form Interface shown in Figure 2 below can be transferred directly into Microsoft Excel and analyzed by code and the Data Organization Algorithm.

2.3 Data Collection

Responses to the questions posed will determine in which category to place an individual student. The first step (primary skill/personality) involves a skills and personality survey and data collection. Once the data is collected, it goes through a Data Organization Algorithm. Then each student is given a label based on what is determined to be their most dominant skill. If needed, a secondary skill/personality label can be given to each student. Teams are then constructed to include an appropriate distribution of primary skills/personalities within each group.

Next, category average collects data in a similar fashion as in the first step although this option consists of a program that gives each student a score for each designated category. With these categorical scores, the data is run through the algorithm and each team is compiled to meet a range of averages for each category. This will ensure that each team has a balance of skills within each sub-classification. Principal component analysis tools will be used to further analyze the data, separating large data sets into distinct groups.

Finally, the overall rank involves giving each student an overall score based upon the survey results. Groups will be assembled to place students with high overall scores with the students who scored lower. Each overall group score will fall between a specified range.

1	Person 1	4	5	3	2	2	5	2	4	1	2	3	4	2	5	4
2	Person 2	4	1	2	3	3	4	2	1	4	5	1	3	2	1	3
3	Person 3	1	5	2	2	1	5	4	4	4	5	1	2	1	2	4
4	Person 4	5	3	2	3	5	1	2	4	2	1	1	5	4	2	2
5	Person 5	1	2	2	2	2	3	2	4	5	2	4	5	4	5	5
6	Person 6	5	3	5	2	2	2	3	3	1	4	1	5	3	5	5
7	Person 7	4	2	5	5	3	2	5	4	3	2	2	1	2	5	4
8	Person 8	5	3	2	3	3	1	1	5	3	4	4	4	2	1	2
9	Person 9	5	2	3	2	5	1	1	1	2	4	1	5	2	3	4
10	Person 10	2	1	1	3	1	1	1	3	1	3	5	1	5	3	3
11	Person 11	5	3	2	1	1	5	3	3	2	4	5	1	2	3	3
12	Person 12	1	3	1	5	1	3	2	3	4	4	3	3	2	1	3
13	Person 13	4	4	2	1	2	4	1	2	2	4	2	5	1	3	5
14	Person 14	3	2	1	5	2	1	2	3	1	1	2	3	4	5	3
15	Person 15	2	4	1	5	4	2	5	1	2	3	2	1	3	3	1
16	Person 16	4	1	1	1	1	3	5	5	5	1	1	1	3	3	1
17	Person 17	2	4	2	5	4	4	4	2	2	4	2	5	1	1	5
18	Person 18	1	5	1	5	1	2	3	5	3	4	2	5	3	3	3
19	Person 19	1	4	3	3	5	5	1	2	4	5	3	2	3	4	2
20	Person 20	3	3	1	3	4	3	3	1	3	5	5	3	5	4	1
21	Person 21	5	4	5	1	5	3	5	4	2	5	1	3	5	5	1
22	Person 22	1	1	5	3	3	3	5	2	4	2	4	1	4	3	1
23	Person 23	2	5	1	5	2	3	4	4	4	2	1	5	3	2	5
24	Person 24	3	2	4	1	5	3	1	4	4	4	5	3	2	4	3
25	Person 25	1	3	2	4	2	4	1	1	3	3	2	2	4	4	4
26	Person 26	2	1	5	3	2	4	5	5	5	4	3	1	2	2	5
27	Person 27	4	3	2	3	4	5	2	4	1	2	1	3	1	1	4
28	Person 28	2	4	5	2	2	3	5	5	4	4	2	4	2	3	5
29	Person 29	1	2	4	3	5	1	3	5	1	2	5	5	5	2	4
30	Person 30	5	3	4	1	3	1	2	4	5	1	4	4	4	1	1

Figure 2: Summary of collected data from 30 students

2.4 Algorithm

The Data Organization Algorithm (DOA) takes the data from a long list of student responses and organizes it such that it can create teams according to the professor's specifications. A general flowchart of how it accomplishes this can be seen below in figure 3:

The Algorithm operates in five major stages:

1. Data Collection Stage (student survey responses)

e-ISSN: 2250-0758 | p-ISSN: 2394-6962
Volume-11, Issue-6 (December 2021)
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2. Data Analysis Stage
3. Role Assignment Stage
4. Grouping Stage
5. Output Stage

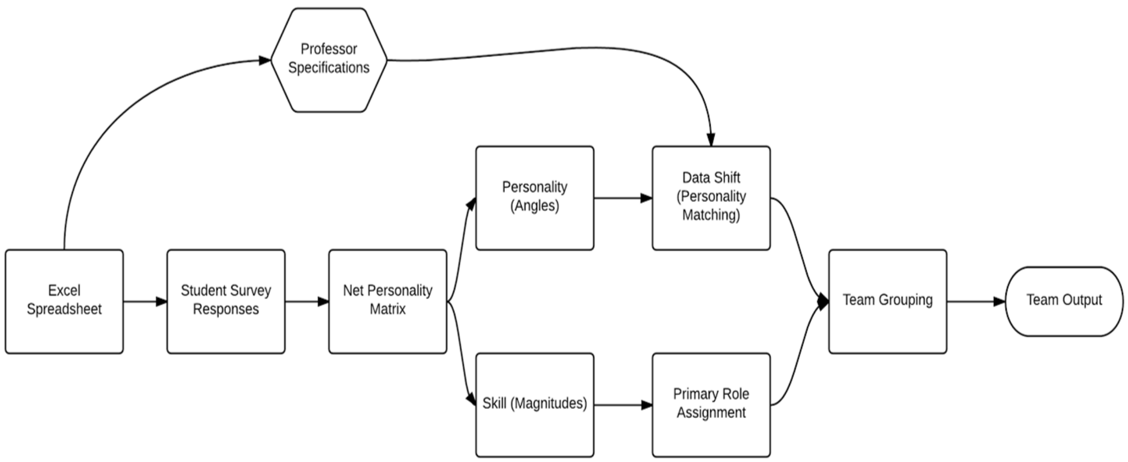

Figure 3: Order of operations flow chart for the team formation software

III. RESULTS

3.1 Observation Matrix

The algorithm utilizes the data provided by the survey spreadsheet output. After accessing the excel file the script organizes this data into an **m** by **n** matrix, where **m** is the number of questions and **n** is the number of students. Thus if there are fifteen questions and twenty-five students the algorithm will begin analyzing 375 data entries. Each data entry is a response to the question on a scale of one to five. This collection is called the Observation Matrix. The Observation Matrix contains three rows for every question: the serious assessment, the causal assessment, and the general assessment.

The observation matrix is then split into two matrices: one that houses the general skill of the individuals, and one that houses the personality dependent portion of the skills. This turns the matrix into a complex set of matrices of the form **A**+ j* **B** where **A** is the general skill matrix and **B** is the personality matrix. This transforms each student entry into a complex number of the form **a** + j***b** where **'a'** is their response to the general skill question, and **b** is their net response to the personality questions.

The magnitude is simply calculated by taking the root of the squares of the real and imaginary portions of the response, and the angle is calculated via the inverse tangent function.

This format now condenses the results to two measurements: skill and personality. Formerly, there were three skill measurements (skill, personality and angle) acting independently without a meaningful personality component.

3.2 Skills Sorting

At this stage, the students are organized according to their skills in order to pick out which ones will be leaders, artists, etc. To accomplish this, the algorithm sorts the magnitude matrix according to each skill in descending order. Thus when sorted according to row one (leadership, for example) the highest ranked leaders will now appear on the left instead of in alphabetical order by name. The algorithm then takes the top five out of the pool, and puts them into their own 5x5 skill matrix. This process is then repeated for all skills. Note that this means the order in which the skills are organized matters, making it important to perform the highest priority skill first. For example, if the top priority is that every team receives a good leader, the leaders will be chosen first.

At this point, the Algorithm performs a shift according to the category weights the professor specified in the Excel sheet. For example, if the professor specified that they want the algorithm to bias student athletes together the algorithm will add a second parameter to the matrix in order to sort the students together. The professor may specify more than one predefined sorting parameter, but each subsequent parameter will reduce the overall efficacy of the algorithm.

Once the algorithm has matched members across skill groups based on personality and special parameters, the algorithm outputs the teams as shown in the template in Figure 4.

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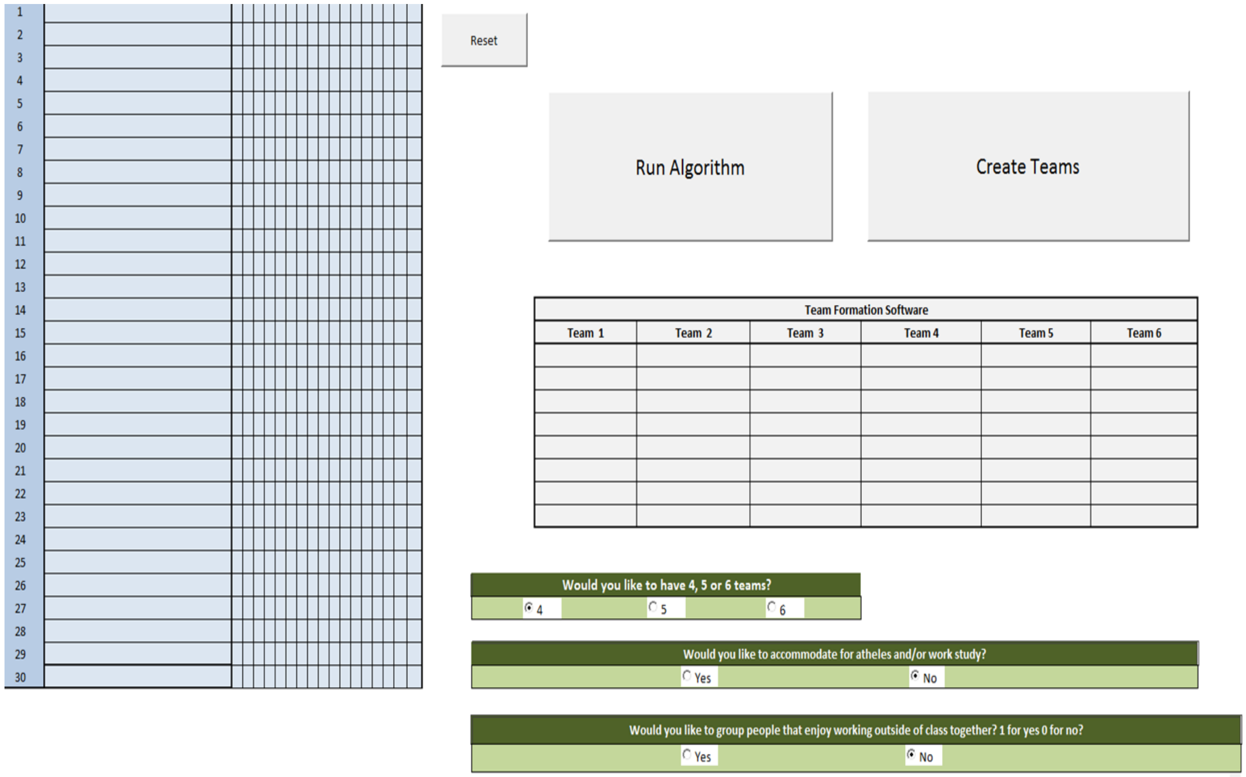

Figure 4: Tool interface where input and output data will be populated

3.3 Teams Creation and Display

As an illustration, random data was used an input to the software. Figure 5 displays the six teams created after a total time of forty-five seconds. A post processing analysis of the results was conducted to inspect the quality of teams generated.

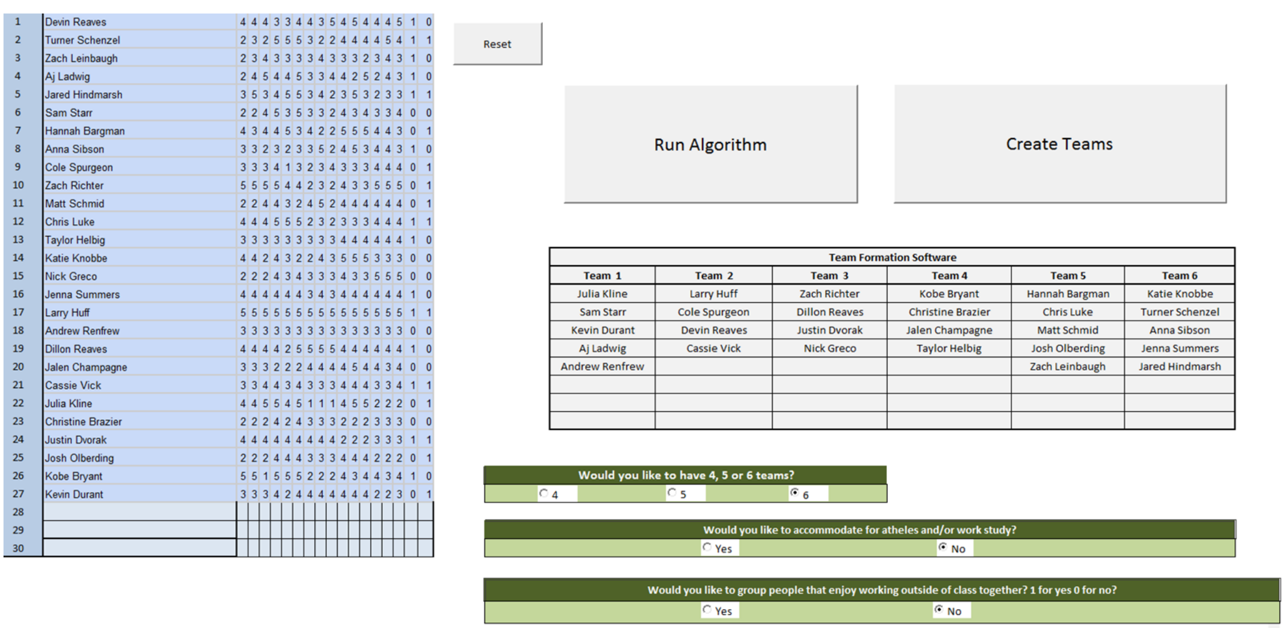

Figure 5: Team creation display

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Volume-11, Issue-6 (December 2021)
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3.4 Roles and Skills Distribution

Using random data generated in Figure 2 as input, the algorithm has generated a total of five teams. In this section we look at team generated and discuss distribution of the roles and personality among the teams. The standard deviation of the skill distribution varies between 0.27 and 0.76 as a reminder, the even distribution of skills among a team rather the presence of highly skills is more likely to produce effective teams. Figure 6 shows the presence of key role in a given team (team 2 in this case).

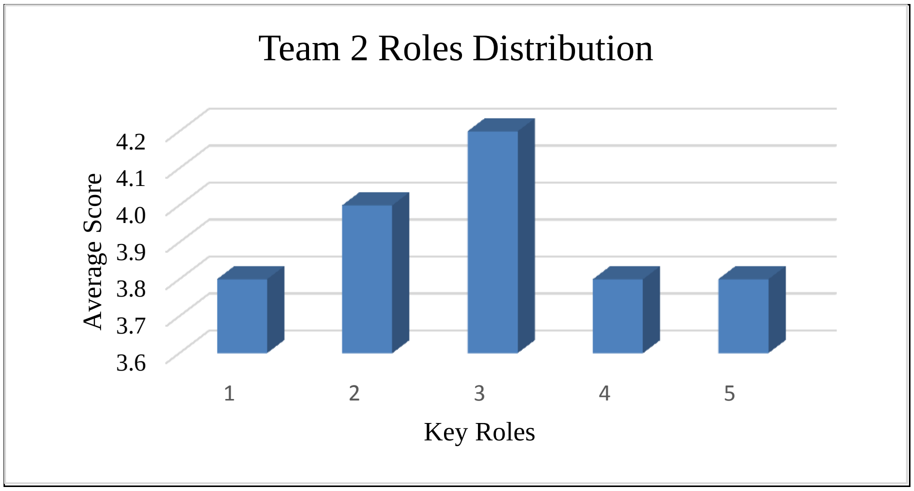

Figure 6: Roles distribution in a given team

Figures 7 and 8 indicate the presence of different roles in the teams and the even distribution of the skills within the teams.

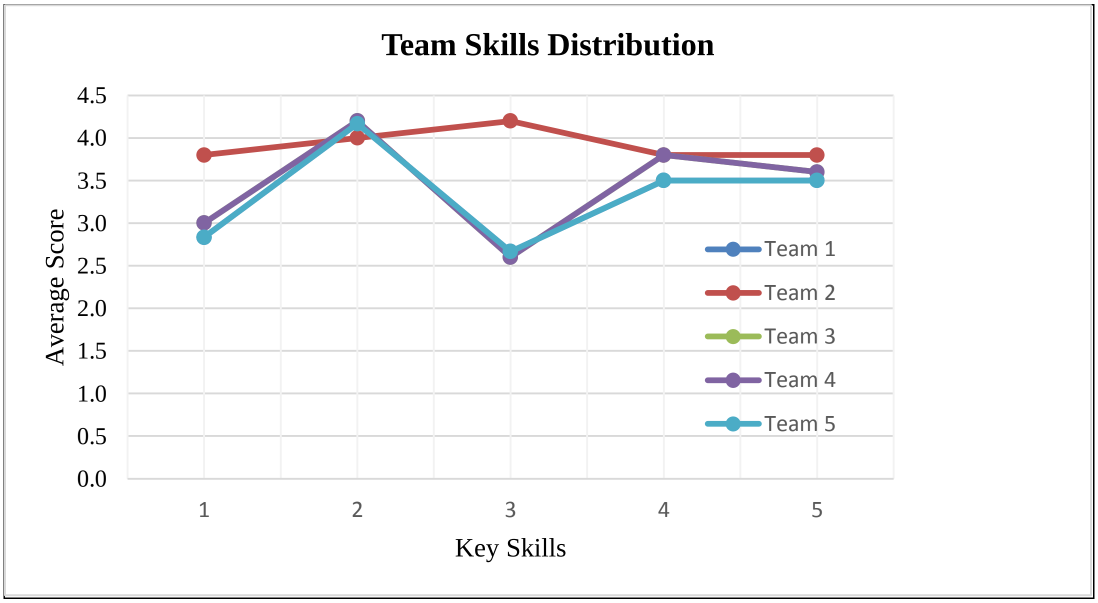

Figure 7: Skills distribution

e-ISSN: 2250-0758 | p-ISSN: 2394-6962
Volume-11, Issue-6 (December 2021)
https://doi.org/10.31033/ijemr.11.6.10

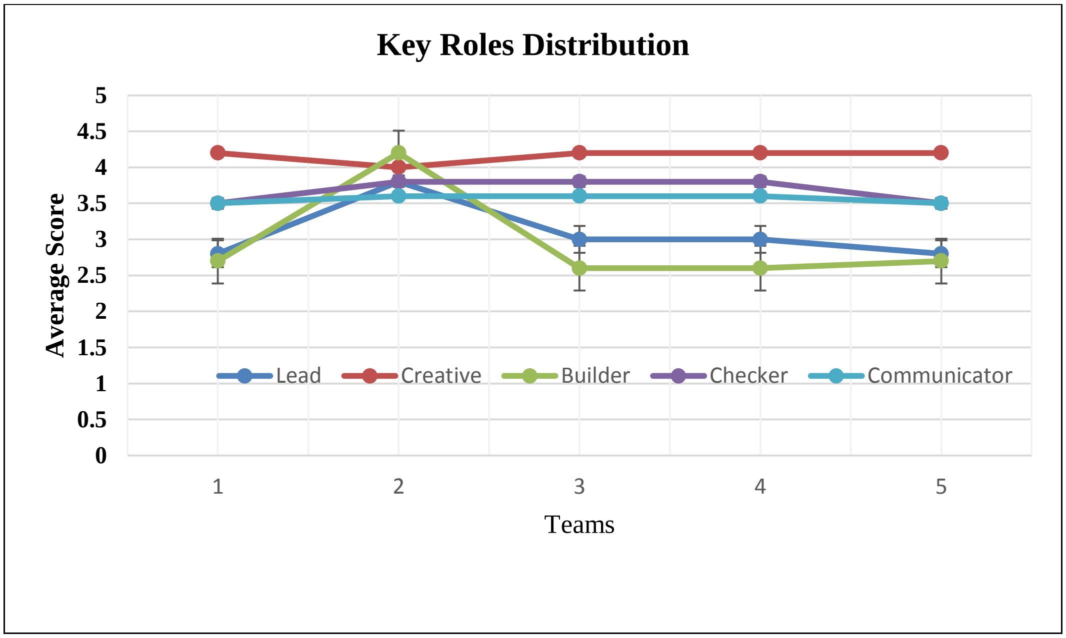

Figure 8: Role distribution in and across teams

IV. CONCLUSION

A team formation tool has been described in this paper. The developed tool is a software made of hybrid Excel and MATLAB, with google interface for data collection. The data, collected through a google interface, is consolidated in an Excel spreadsheet and entered as a matrix in a MATLAB script. The test consisted of a class of 30 students and random data created. The tool output five teams of 6 persons each after 45 seconds. An analysis of the teams created indicates the presence of different roles in the teams and an even distribution of skills in the teams created with a standard deviation varying between 0.27 and 0.76

Further work will include the comparison of performance between the created with this tool and teams created from other traditional team formation tools.

ACKNOWLEDGMENT

Jeremy Ansah-Twum, Bradley Lloyd, Tyler Heather, Devin Reaves, Patrick Cordes, and Michael Elliott

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