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Contextualizing Teamwork in a Professional Communication Course for Engineering Students*

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The paper outlines evidence from studies concerning the importance of professional communication for engineering students. This is followed by description of syllabus change at the American University of Sharjah to address a perceived need for professional communication skills. The paper then reports the procedures employed to contextualize these skills through engineering multidisciplinary projects (EMDPs). Discussion of the use of the Belbin Get-Set Self Perception Inventory (SPI) to develop team-role behavior is considered. The paper outlines an investigation of the perception that student understanding of team-role behavior is positively influenced by self-awareness and the contextualized work undertaken in EMDPs. The data used in this investigation were the preference scores obtained from two administrations of the Belbin Get-Set Self Perception Inventory (SPI) with three cohorts of students (n = 56), at the commencement and completion of Spring Semester, 2011. Values from the two administrations of the Belbin SPI were tested to establish whether there was statistically significant improvement. Findings indicate positive change in students' understandings of the significance of team-role behavior. At ten per cent (10%) of significance strong evidence of significant improvement in four categories was recorded for individual results and in three categories for team results.

Keywords: engineering multidisciplinary projects; professional communication; team role behavior; team-building; collaborative

1. The need for the development of communication skills and personality attributes

Colleges of Engineering have become increasingly aware of the need to provide more than the traditional technical discipline-based education for their students. A sound knowledge of engineering theory and practice alone is no longer sufficient to meet the demands of the market place. Students graduating from engineering programs are expected to possess an effective range of communication skills, to have developed collaborative work practices and to possess a clear understanding of social responsibility and ethical practices. Considerable documented evidence illustrates the reality of these skills as essentials for young engineers. In a recently published Australian study undertaken with 300 engineers with experience of between 5 and 20 years Male, Bush & Chapman [1] have shown that competency deficiencies in engineering business, communication skills, self-management and attitude, problem solving and teamwork are areas for improvement in engineering curricula. These findings reflect other studies which have also highlighted such competencies as in need of improvement. An international survey [2] of 1091 chemical engineers during their first five years of employment found deficits in management, effective communication and leadership, attributes are identified in other studies as among the most important for graduate engineers [3, 4]. Male, Bush & Chapman assert "communication is the competency that features most frequently as a deficiency in Australian surveys" [1, p. 56] and work conducted by Ashman et al [5] and Nair et al [6] concurs.

Competencies that are deemed essential but often deficient in engineering workplace situations, have been identified either by engineers reflecting on their self-perceived shortcomings or by experienced engineers observing the limitations of junior colleagues. Either way, the necessity for effective communication and management skills is clear. The impact of information communications technology (ICT) has made attainment of these skills significant due to opportunities available for collaboration and communication between professional colleagues.

Recognition of this reality is embodied in the Carnegie Mellon University Department of Engineering and Public Policy (EPP) which seeks to develop in students an understanding of the interface between society and technology and the skills that will enable effective work at that interface. Students in the EPP department study their engineering degrees in the context of the social and ethical expectations that are increasingly important for the engineering professional and learn how to "seek advanced assistance . . . in areas beyond the traditional expertise of engineers" [7]. Furthermore, the Carnegie Mellon degrees recognize the need to develop collaborative work practices as students are expected to "demonstrate an ability to integrate conventional technical analysis with behavioral and other social issues, where the engineer is a

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participant in teams composed of many disciplines" [7]. This recognition of inter-disciplinary study resonates with the work at the American University of Sharjah (AUS), described later in the paper.

The OECD's 'Definition and selection of competencies: theoretical and conceptual foundations' (DeSoCo) project is foundational to research emphasizing the need for engineers to be able to integrate technical expertise with behavioral and societal issues and to exhibit high level communication skills. The DeSoCo project work, published under the editorship of Rychen and Salganik [8], developed a conceptual frame of reference for key competencies. It was based on theoretical and conceptual approaches to competence informed by political and practical considerations. The rationale for the work took into account the fact that rapid and continuous change in technology required adaptability rather than mastery; social diversity necessitated different kinds of personal relationships (more contact with those different from oneself); globalization created interdependencies with actions subject to influences and consequences beyond regional and national boundaries (economics and pollution for instance). This seminal project is reflected in work conducted by Trevelyan and Faulkner. Trevelyan [9] noted that much engineering practice among interview participants in a 2007 study was coordination of technical work of others and that social interactions were central to this practice [10], while Faulkner [11] designated the work of engineers in her study as sociotechnical. Male [12] asserts that such studies indicate that engineering communication encompasses many interactions, often outside formal meetings, presentations, and reports, to coordinate people without formal lines of authority.

2. Engineering and communication at the American University of Sharjah

The mission of the AUS College of Engineering (CEN) recognizes the fact that English fluency is a necessary condition for success in a global economy and therefore a strong emphasis is placed on developing excellence in communication skills, both written and oral. The United Arab Emirates is located on the crossroads between East and West and most AUS graduates will work in an international environment, so value is also placed on global awareness and cultural sensitivity. All undergraduate degree programs in the CEN are accredited by the Accreditation Board for Engineering and Technology Inc. (ABET) of the United States. ABET accreditation requirements have compelled course planning to address the need engineers have for competencies beyond a sound technical knowledge, engineering skills and technical writing ability. Cross discipline planning and course development has transformed a technical writing course, into a language and communication training course for undergraduate engineers in profession-oriented collaborative, communication and academic skills.

2.1 Background to change

Prior to the Spring Semester, 2010 the CEN, acting upon ABET recommendations designated a technical writing course a prerequisite study for engineering students. Furthermore the Dean of CEN requested the Department of English to incorporate an engineering multi-disciplinary project into *ENG207: English for Engineering* in order to provide the engineering undergraduates training in a range of collaborative, communication and academic skills (Appendix A). Accordingly a pilot program was developed and implemented during the Spring Semester, 2010 with three of the ten sections in the course. A cross-discipline management team drawn from the College of Arts & Sciences and the College of Engineering (CEN) and the Dean from the CEN met regularly to oversee the change [13]. Following the success and the apparent potential of the pilot program the change was applied to the full cohort in Fall Semester, 2010.

Other factors influenced this change in that it was also made in response to employers' and students' concerns that AUS engineering trainees and graduates lacked the skills needed for communication with co-workers, supervisors and employers. As a consequence, it is now policy that AUS engineering students study *ENG207* during their junior year before prior to senior design project work and internship. ABET endorsed the specification that engineering students from different majors should participate in engineering multidisciplinary projects (EMDPs) that require individual and collaborative input from each of the students in the team. Since this proved difficult to implement in specialized engineering courses Schmidt [14], where students from different majors generally study separately from others, the most suitable context for the change was *ENG207* which comprises students from all engineering disciplines and from different cultural and ethnic backgrounds.

2.2 Contextualizing the change

The revised course syllabus requires students to work in multidisciplinary teams, drawn from different majors, make a succinct collaborative oral presentation, make a poster presentation and produce a written report on their multidisciplinary projects. Other important aspects of the revised course facilitate the multidisciplinary team work. Students are trained to conduct effective meetings, to plan and document decisions, to set planning goals and meet deadlines, to manage themselves and their peers, to show leadership and to evaluate their peers. There is emphasis on responsibility at personal, inter-personal and community levels and the start of a sense of a community of professional practice.

The course also aims to instill leadership qualities anchored in moral and ethical principles. This reflects the need engineers have for competencies beyond possessing sound technical knowledge and engineering skills. Again this is an ABET determined requirement. Perusich et al [15] have observed "Most engineering and technology graduates will work in business on projects that have significant complexity and require multiple skill sets". CEN graduates will require teamwork attributes of mutual accountability, interdependence and complementary skills in order to achieve common goals and pursue common purposes

There is ample evidence that teaching and learning about professional communication skills out of their appropriate settings does not guarantee full student involvement in the learning process and may be ultimately futile, Mercer [16], Yu [17] and Chun [18]. Contextualizing the teaching of these skills within the engineering multidisciplinary project (EMDP) demonstrates their appropriate uses in authentic communication situations. Work by Paris and Winograd [19] has showed that transferring responsibility for monitoring learning to students through development of problem-solving strategies improves their learning because of an increased awareness of their thinking in applying these strategies. Improved levels of motivation and positive self-perception may also result and the social exchange environment of effective teamwork reveals aspects of Vygotsky's [20] theory of socially mediated learning.

2.3 Self-regulation

A further aspect of the changes incorporated in the revised syllabus is predicated on Zimmerman's [21] concept of 'self-regulation'. He states that self-regulation is the "self-directive process by which learners transform their mental abilities into academic skills" [21, p. 65]. Self-regulated learners are "metacognitively, motivationally, and behaviorally active participants in their own learning process" [22, p. 329]. To accomplish their goals, learners set personal goals, perform strategically, monitor their progress, and adapt their approach. These skills are important for young professionals and for their future needs to be active lifelong learners. Zimmerman [21] has identified a number of strategies for self-regulation which are germane to the individual and collaborative work which our students must contribute to their engineering multidisciplinary projects. These strategies include systematic self-evaluation, goal-setting and planning, seeking information, keeping records and monitoring and reviewing records.

2.4 Team role behavior

The syllabus change that now requires students to work in multidisciplinary teams has placed emphasis on team-role behavior with resulting prominence given to personal, inter-personal and team learning. These teams are formed in compliance with the following requirements; teams must be comprised of three or four students and each team must contain students from at least three different engineering major disciplines. The requirements are to ensure multi-disciplinary project and teamwork. Team building as a phase of the students' EMDP work is discussed in detail by Prescott et al [23].

Students engage in team-building informed by the administration of the Belbin Get-Set Self Perception Inventory (SPI), [24] used to provide both individual and team profile preferences of the nine roles deemed by Belbin as essential for well-functioning teams. Use of this instrument is intended to raise students' awareness of the characteristics of team-role behavior and assist them to develop their capacities to work together in coordinated, interdependent ways. Understanding the significance of the different roles that constitute effective teams is considered to aid this development. Belbin Team Roles are used to identify behavioral strengths and weaknesses and the reports the students each receive enable them "to build mutual trust, understanding and productive working relationships" [24] Student collaborative use of their individual Belbin reports within a team helps both the individual and the team develop self-awareness and increase effectiveness. The students' engagement with multidisciplinary teamwork is believed to enhance this development and lead to a more informed understanding of team-role behavior.

The Belbin Get-Set Self Perception Inventory (SPI) is a measure of perceived preference for the nine different team-role behaviors rather than an actual measure. Instead of providing information regarding individual personality traits, the SPI gauges behavior in order to identify groupings or clusters (Team Roles) which characterize an individual's behavioral contribution to the team. An individual has a combination of preferred, manageable and least preferred roles. As the Belbin documentation makes clear "the distribution and interrelation of these roles across an individual's profile have a great influence on the way the roles will be played out in practice and experienced by others. Whilst an individual may claim to prefer or enjoy a particular role, it does not necessarily mean that they can or should play only this role'' [24]. This measure has been found to have high face validity; Balderson & Broderick [25] while Dulewicz [26] established the criterion validity of the Belbin Team Roles in making teams more successful. Balderson & Broderick have further reported that there was no significant gender bias for any Team Role.

3. Objective of the study

In order to test the perception that students' understanding of team-role behavior is positively influenced by self-awareness and appreciation of the need to work cohesively in teams, an investigation was conducted with the individual results of three cohorts of ENG207 students at the beginning and end of the Spring Semester, 2011. A further aspect to the investigation was an examination of team results also at the beginning and end of the course. Variations in performance for individuals and teams are presented and discussed in the following section where the investigation is considered.

4. Investigation context

At AUS, standard practice has developed to require all engineering students registered in the ENG207 course to undertake the Belbin Get-Set SPI at the start and at the end of a semester. The initial results help students work consciously to develop weaknesses and consolidate strengths in accordance with their team role profiles. This procedure complements the engineering multi-disciplinary project (EMDP) work which forms the core of the collaborative endeavor in the course. For instance, the attributes 'plant', 'resource investigator' and 'shaper' are required in the initial stages of the projects when teams have an urgent need to generate ideas, identify resources, plan ahead and make decisions. A team which understands any preferential weaknesses in these roles can swiftly move to address the situation and remedy weaknesses by a combination of awareness and developmental exercises. Conscious decisions to actively develop deficient attributes have been shown to benefit understanding and performance of student teams. Other attributes such as 'coordinator', 'teamworker', 'implementer' and 'monitor/evaluator', needed in the middle stages of the EMDP work similarly benefit from awareness and enhancement. Attributes such as 'completer/finisher' and 'specialist' generally become stronger preferences towards the end of the project. It is at this stage that teams have need for the qualities of the 'completer/finisher' to guarantee adherence to project deadlines. The other attribute, 'specialist', may often increase in preference as a result of students' gaining specialist engineering knowledge from team members belonging to other engineering disciplines. At the conclusion of the semester students take the SPI again and results are compared for significant changes in the students' personal profiles.

4.1 Data source

The data used in this investigation were the preference scores obtained from two administrations of the Belbin Get-Set Self Perception Inventory (SPI) with three cohorts of ENG207 students (n = 56), one at the commencement of the Spring Semester, 2011 and the other near the completion of the same semester. The Belbin Get-Set SPI scores result from interpretation by a Belbin program which indicates which of the nine team-roles students have a preference for and which they don't. The nine team-role behaviors are: Plant, Resource Investigator, Co-ordinator, Shaper, Monitor/Evaluator, Team-worker, Implementer, Completer/Finisher, and Specialist. These are the team-roles that are considered by Belbin Associates as essential for balanced teamwork. Experience with junior year engineering students suggests that identification of both individual and team preferences raises student awareness of strengths and identifies areas of weakness that can be consciously developed.

Each of the Belbin Get-Set Self Perception Inventory team-role behaviors was plotted on a scatter chart with values ranging from 0–100. The values for the nine team-role behaviors for each one of the 56 students in the study cohort, as well as the team values, were recorded at the start of the Spring Semester, 2011. The same procedure was followed at the end of the semester and results were compared. In this examination and comparison process values were tested to establish whether there was statistically significant improvement.

5. Study hypotheses

The following hypotheses were assumed:

H_o: There is no significant improvement in the total scores.

H_A: There is significant improvement in the total scores (claim).

6. Results

6.1 Individual results for study cohort

Figure 1 shows the study cohort individual results for the Belbin Get-Set SPI at the beginning and end of the semester. The totals indicate a positive shift in the study cohorts' individual results.

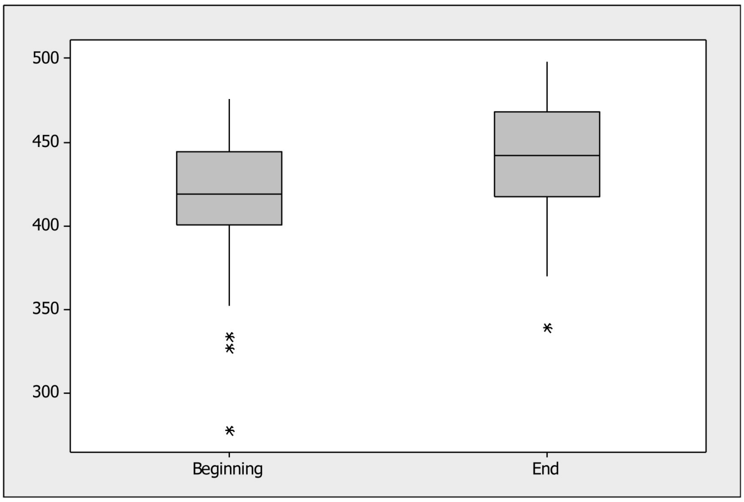

Fig. 1. Belbin Get-Set SPI total individual scores, beginning and end of semester.

To establish if the difference was statistically significant, the authors conducted the non-parametric test Wilcoxon Signed-Rank [27] as the total scores were not subject to distribution limitations. The difference for the results beginning semester and semester end were computed and labeled as "total d". The result obtained is given in Appendix B. If the individual categories are considered, the analysis shows that there is a significant improvement at the end of semester in results for these four team-role categories: Specialist (SP), Implementer (IMP), Plant (PL) and Coordinator (CO). Other categories show no significant improvements.

6.2 Individual results for team-role categories

The positive finding in hypothesis testing for the total results was followed by examination of the individual team-role categories. To establish if the perceived difference was statistically significant we again conducted the non-parametric test Wilcoxon Signed-Rank. At ten per cent (10%) of significance strong evidence of significant improvement in the results of the categories: Specialist (SP), Implementer (IMP), Plant (PL) and Coordinator (CO) were identified. Figs. 2–5 (Appendix C) show the study cohort individual results for these four team-role categories at the beginning and end of the Spring Semester, 2011.

At a significance level of 10% it was determined that there was no evidence of significant improvement in the results of the categories: Monitor/Evaluator (ME), Sharper (SH), Team-worker (TW), Resource Investigator (RI) and Completer/Finisher (CF). In these categories either the results remained the same or slightly decreased between the beginning and the end of the Spring Semester, 2011. These results are not included in this paper.

6.3 Team results

Team results for the beginning and end of Spring Semester indicated a positive shift in the results for the sixteen teams in the study cohort. These results are shown in Fig. 6 in Appendix C. Examination of the graph of the total scores for the sixteen teams in the study cohort also indicated that a majority of the teams had an improved total score at the end of the semester.

6.4 Team results for team-role categories

Furthermore, if individual categories are considered in aggregate, the results show a significant improvement across teams at the end of semester for the categories: Specialist (SP), Implementer (IMP) and Coordinator (CO). The remaining six categories did not show any significant improvement at the end of semester. Nevertheless, we again conducted the non-parametric test Wilcoxon Sing-Rank test to find out if the scores were better at the beginning of semester. We found that only one category, Completer/Finisher (CF), registered significantly better scores at the beginning of the semester. Thus it was concluded that the other categories Plant (PL), Monitor/Evaluator (ME), Shaper (SH), Team-worker (TW) and Resource Investigator (RI) either remained same or registered only slight insignificant differences between the beginning and end of semester. These results are not included in this paper.

7. Reflections

The Belbin Get-Set Self Perception Inventory (SPI) administration is used with AUS junior year engineering students to develop their awareness of both individual and team preferences for the nine team-role behaviors considered necessary in well-functioning teams. This understanding helps the students build their capacities to work together in coordinated, inter-dependent ways and enables the successful teamwork needed to support quality work in their engineering multi-disciplinary projects. The work is preparatory to the capstone academic exercise, Senior Design Project which is of considerable importance for CEN students.

Other research has attested to the positive effects that use of the Belbin team roles can have with students. Blignaut and Venter [28, p.270] report that "The majority of students indicated that working in teams contributed to their understanding of the subject, that they gained on a personal and social level and that they have learned more in the team than they would have by learning individually. This method of teaching results in the development of positive relations and desirable pro-social behaviors which can possibly bridge the gap between tertiary education and the job market".

Two broad observations can be made concerning the results. First they indicate the dynamic nature of the students' teamwork and the cognitive development that accompanies it. The vast majority of students enter ENG207 having experience of group work but little notion of teamwork and how it differs from working in a group. Work with the Belbin team-role behaviors addresses this deficiency to a certain extent but the real growth in understanding arises from engagement in the engineering multi-disciplinary projects. The observations made earlier in this paper concerning the place of contextual teaching and learning, and supported by Predmore [29] and Workman et al, [30] are germane. The thematic and contextual coherence afforded by the EMDP team work motivates students to develop their individual and interdependent team-role behaviors as a response to surmounting the challenges of their project work. Building capacity in requisite team-role behaviors arises from growing awareness of the significance of various team-roles and the diverse demands of the tasks associated with the EMDP. Shifts in students' individual perceptions shown in the results of this investigation involve team-role behaviors in social, cognitive and an achievement domain; that is in the action oriented Implementer IMP, the thought oriented Specialist SP and Plant P and the people oriented Coordinator CO.

The second observation is that shifts in perception are to be expected if a team develops the collaboration, interdependence and mutual accountability that characterize effective dynamic teams. This is clearly identified in Belbin literature, "Whilst most personality traits are acknowledged to be fairly constant, behavior can change more readily, adapting to changes in any of those factors which influence it" [31, p. 3].

8. Conclusions

The study showed that the perception that students' understanding of team-role behavior is positively influenced by self-awareness and appreciation of the need to work cohesively in teams to be verified. Significant improvement in the total scores was evidenced in four team role behaviors. The study objective was therefore achieved.

There are limitations to this investigation. The findings indicate positive change but lack the confirmation from another data source that would strengthen their credibility. A second clear limitation is that the student sample used in the investigation was 25.45% of the total enrolment. While this might be claimed to be a reasonable representative sample a larger cohort of students would provide stronger results. No attempt was made to investigate differences in gender perception though this would be a fruitful pathway given female enrolment in CEN is around 25% and growing.

A future investigation which seeks the perceptions of the students on the issue of the benefits of understanding the Belbin team-role behaviors through the use of student logs and focus group discussions is planned for Spring 2013.

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Appendix A

Table 1. Assessment structure of the old & new syllabi, ENG207

Previous ENG207 Syllabus	**Revised ENG207 Syllabus**
Document Organization 1. Curriculum vitae 2. Job application letter Technical Presentation 1. Proposal 2. Progress report 3. Technical presentation Report 1. Proposal & draft 2. Executive summary 3. Final report Test & examination 1. Mid-semester 2. Final examination	Document Organization 1. Curriculum vitae 2. Job application letter Engineering Multi-Disciplinary Presentation (EMDP) 1. Topic Choice & Approval 2. Proposal Submission 3. Oral Progress report 4. Poster presentation Meeting, Planning Documentation 1. Minutes of official team meetings 2. Documentation of informal team meetings 3. Documentation of key decision-making 4. Documentation of planning 5. Gantt Timeline planning EMDP Report 1. Proposal & draft 2. Executive summary 3. Transmittal letter 4. Final report Peer evaluation 1. Six point attribute rating scale Test & examination 1. Mid-Semester Reflection 2. Final examination

Appendix B

Wilcoxon Signed Rank Test: total d

Test of median = 0.000000 versus median < 0.000000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
Total d	56	55	362.5	0.000	-23.25

Since the p-value was very small it was concluded that that there was significant improvement in the second test results. This positive increase indicated that was supported.

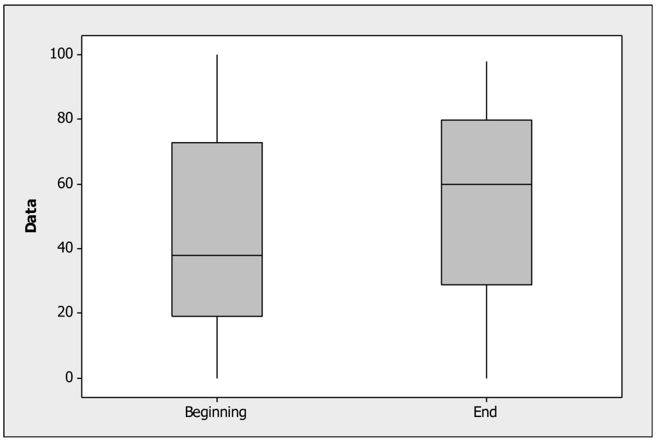
Appendix C

Study cohort individual results for these four team-role categories of the categories, Specialist (SP), Implementer (IMP), Plant (PL) and Coordinator (CO).

Wilcoxon Signed Rank Test: Specialist d

Test of median = 0.000000 versus median < 0.000000

	N	N for Test	Wilcoxon Statistic	P	Estimated Median
Specialist d	56	51	434.0	0.016	-8.000



In the test the p-value obtained was 0.016 so it can be concluded that there was significant improvement in the Specialist SP results at the end of the semester. Level of significance is 10%.

Fig. 2. Belbin Get-Set SPI total individual scores specialist category, beginning and end of semester.

Wilcoxon Signed Rank Test: Implementer d

```
Test of median = 0.000000 versus median < 0.000000

                     N for   Wilcoxon                Estimated
                N    Test    Statistic         P        Median
Implementer d  56      53        533.0     0.054        -7.000
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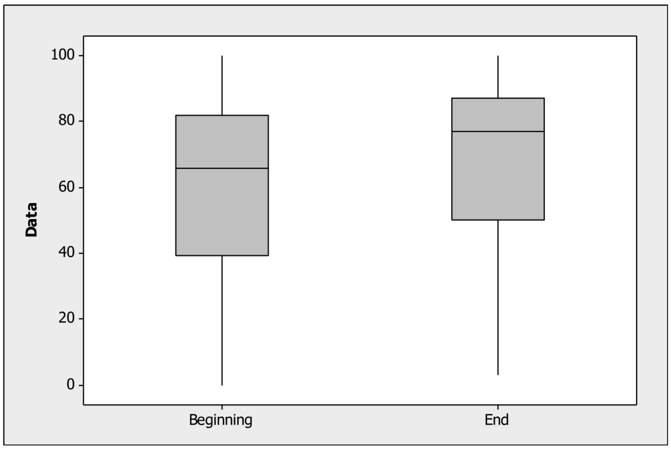

In the test the p-value obtained was 0.054 so it can be concluded that there was significant improvement in the Implementer IMP results at the end of the semester. Level of significance used is 10%.

Fig. 3. Belbin Get-Set SPI total individual scores implementer category, beginning and end of semester.

Wilcoxon Signed Rank Test: Plant d

```
Test of median = 0.000000 versus median < 0.000000

                     N for   Wilcoxon                Estimated
                N    Test    Statistic         P        Median
Plant d        56      52        489.5     0.035        -8.500
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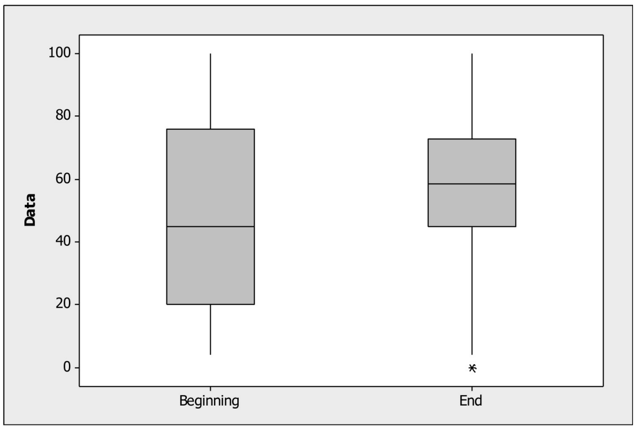

In the test the p-value obtained was 0.035 so it can be concluded that there was significant improvement in the Plant PL results at the end of the semester. Level of significance used is 10%.

Fig. 4. Belbin Get-Set SPI total individual scores plant category, beginning and end of semester.

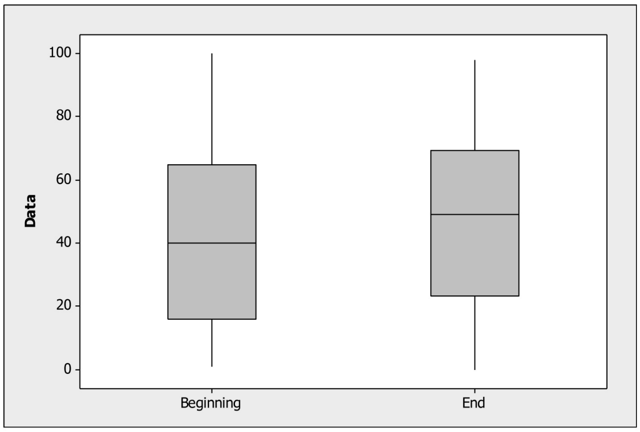

Fig. 5. Belbin Get-Set SPI total individual scores coordinator category, beginning and end of semester.

In the test the p-value obtained was 0.072 so it can be concluded that there was significant improvement in the Coordinator CO results at the end of the semester. Level of significance used is 10%.

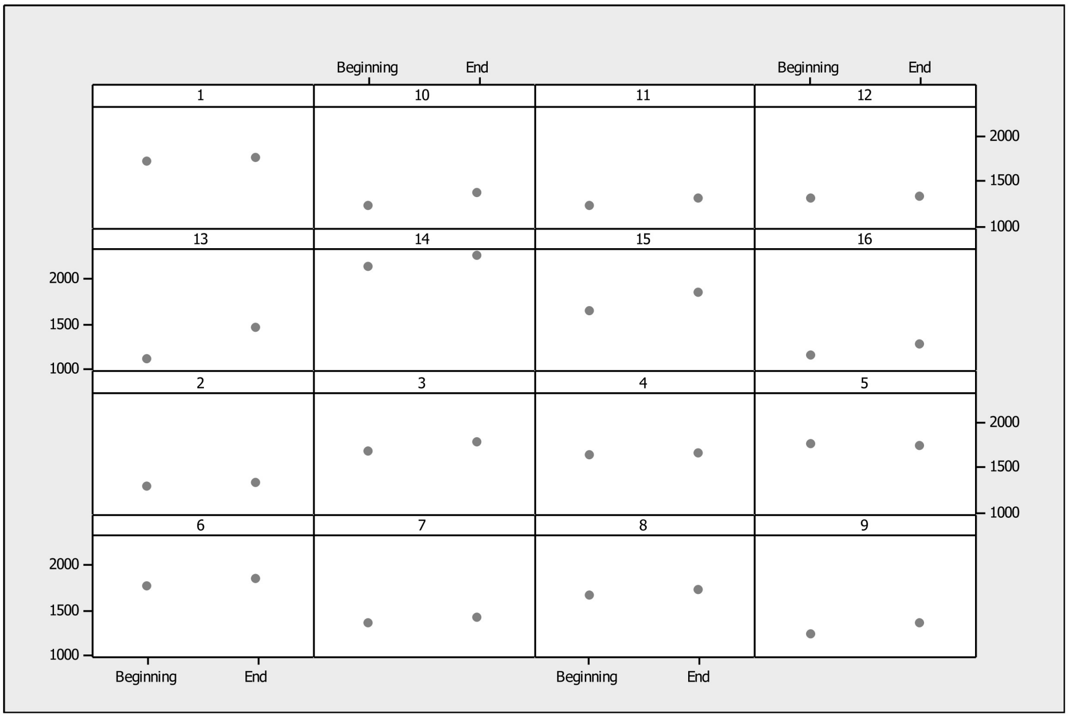

Fig. 6. Individual value plot of total scores for 16 teams on beginning and end of semester.

Again the non-parametric test Wilcoxon Sing-Rank was conducted to establish whether the improvement was statistically significant or not. The test result obtained was as follows:

Wilcoxon Signed Rank Test: Total d

```
Test of median = 0.000000 versus median < 0.000000

                     N for    Wilcoxon              Estimated
              N      Test     Statistic        P       Median
Total d      16        16           2.0    0.000       -87.25
```

Since the p-value was very small it was concluded that there was significant improvement in the team's results at the end of the semester.

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