Assessing Individual Temperament and Group Performance in a Project-Based Learning Experience

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Abstract

An important aspect of the culminating events in most civil engineering programs is to ensure students can work in teams to solve complex engineering problems. In addition to solving problems in the multiple discipline areas of civil engineering and designing civil engineering components and systems, the civil engineering program at the United States Military Academy, West Point, seeks to develop students which function effectively on multi-disciplinary teams.

The purpose of this study was to investigate the relationship between individual temperament and group performance during the final project of an introductory infrastructure engineering course. A key component of the course is a group assignment to conduct a reconnaissance and assessment of a specified location's infrastructure as a potential base of operations in the aftermath of a nuclear catastrophe. The authors employed the Keirsey Temperament Sorter to describe each student's individual temperaments.

The team-driven project-based learning experience in the infrastructure engineering course addresses several of the program's ABET student outcomes. The assessment of these specific ABET student outcomes include direct and indirect embedded indicators. Additionally, the peer evaluations provide a qualitative assessment of the interaction between team members with different individual temperaments and the overall effectiveness of the group.

Introduction

The United States Military Academy at West Point has been educating engineers since 1802, meeting a critical need for the Army and Nation by meeting this mission:

> *To educate, train, and inspire the Corps of Cadets so that each graduate is a commissioned leader of character committed to the values of Duty, Honor, Country, and prepared for a career of professional excellence and service to the Nation as an officer in the United States Army.*

This mission has evolved significantly since the founding of the Academy and that evolution has truly accelerated in the last decade. Creativity, teaming, comfort with cross-disciplinary problems and resilience have become central to the development of Cadets and the mission of the Department of Civil and Mechanical Engineering has become much broader:

> *To educate, develop, and inspire agile and adaptive leaders of character who design and implement innovative solutions and win in complex environments as trusted Army professionals.*

This mission is supported by 16 ABET Outcomes, two of which are critical to the topic addressed in this paper:

- Demonstrate creativity, in the context of engineering problem-solving.
- Function effectively on multidisciplinary teams.

While there is broad agreement across the US about the importance of adding these sorts of outcomes to engineering programs, the ongoing challenge is effectively growing these skills in our students – growing is used deliberately here, since simply teaching the principles of creativity and teaming is not enough. For West Point, as at many others schools, project-based learning (PBL), where students team up to execute ill-defined problems requiring a wide skill set (beyond simply technical), has become essential to growing these skills. In CE350 – Infrastructure Engineering, exactly that approach is taken with the Infrastructure Reconnaissance project described later in the paper.

This paper addresses a key question related to student success in PBL teams: does the temperament mixture of the various team members impact the success of the members? This was evaluated via two complementary studies – first assessing group interaction by means of peer assessment and second, assessing group performance. These assessments were then viewed in the context of the student's temperaments as determined by the Keirsey Temperament Sorter. Results are presented discussing the impact of team composition on both team and peer ratings.

Literature Review

Engineering curricula have been historically very technically focused, with larger classes focused on a specific engineering topic[1]. This style of instruction does not accurately reflect an engineer's job requirements, which often include multi-disciplinary problem-solving and working in groups. Under recent ABET guidance, there has been an increased push for project-based learning that integrates complex, group problem-solving to better align with employer's needs[2]. There is a large body of research related to how to best select individuals for optimum group results[3], which has shown that heterogeneous groups perform best in creative idea generation and decision-making tasks. There is less work however, looking specifically at engineering education and what criteria to use when increasing group diversity. A majority of courses in engineering use fairly simple methods of group selection, based on a random listing, alphabetical by name, student number, grade point average, or simply letting the student's self-select groups. These techniques do not, however, attempt to maximize team diversity in an attempt to improve performance or topic retention. These random groupings may also allow for problems with team cohesion[1] and uneven distribution of total work.

Attempts have been made to maximize team diversity in engineering education settings, however, it is not clear what factors are most important. Combinations of factors including academic strength, gender, ethnicity, work experience, age, and personality measurements have all been researched[4]. Bannerot et al.[5] found that increased age and more work experience increased the probability of a person being a good team member. Hunkler et al.[6] also found that the inclusion of outstanding academic students and those with practical experience increased team performance. A significant amount of research has gone into quantifying the personality traits of engineering students[7], as it may have a causal relationship to group dynamic.

Individual temperaments may interact with others in the group to provide balance or initiate friction during cooperative learning and project-based assessments. The Keirsey Temperament Sorter (KTS) was first introduced in the book *Please Understand Me* by David Keirsey in 1984[8]. His self-assessed personality questionnaire helped identify 16 personality types, which stratified those personality types into four groups by temperament. The four temperaments described are Artisan, Guardians, Idealists, and Rationals. Keirsey describes the Artisans and Rationals as having pragmatic temperaments who pay more attention to their own thoughts or feelings, while the Guardians and Idealists are cooperative and pay more attention to other people's opinions. Keirsey goes into great detail on the impact of temperament on leadership style in his follow up book, *Please Understand Me II: Temperament Character Intelligence*[9], however, he does not reflect on situations where there is a specified group goal with no clear leader. As engineering education continues to move toward increased group work and project-based learning, it is important to identify how individual temperament impacts a group's performance and the individual's retention of course objectives.

The distribution of temperament categories in undergraduate engineering is different from that in the general population. McCaulley[10] found the breakdown of US engineering students to be 39% Rationals, 37% Guardians, 12% Idealists and 12% Artisans, and that the average engineering student is an introverted thinker. Scott et al.[11] found a near equal distribution of introverted and extroverted thinkers in a large sample of University of Tennessee freshman engineering majors, and slightly different breakdown of Rationals (30%), Guardians (34%), Idealists (16%) and Artisans (20%). Others have found an even more skewed distribution, with 63% of civil engineering students identified as guardians, compared to about 40% of the general population, and that Idealists made up 18% of civil undergraduates[12]. Racicot et al.[13] also found greater than 60% Guardians in a mechanical engineering design course. With a reduction in diversity of temperament found in undergraduate engineering, it is necessary to see the impact of varied temperament on student outcomes.

Previous research looking at group performance using the Keirsey temperament scale or other personality index system has been conflicted. Dillon et al.[14] assigned teams based on Keirsey versus self-selected basis. Both groups had similar individual and group grades, and course end feedback was not different between groups. However, there was more personality conflicts in the Keirsey assigned groups and those groups found their design teams worked together less effectively than the self-selected group. Dillon et al. go on to state this may be due to the fact that self-selected groups are usually chosen based on previous personal relationships. Flora[15] and colleagues investigated open experiments over five semesters and 28 groups, some of which students chose the groups and others were assigned based on the Keirsey Temperament Sorter. Overall students worked well with their group, with only 6 out of 109 students giving negative responses, however, any differences based on group selection criteria were not reported. Bannerot et al. found that Myers-Briggs Type Indicators (MBTI) were not a useful predictor of an individual or team's performance[5,16], while Jensen[17] found that teams formed using the Six Thinking Hats (6-Hats) technique or MBTI had higher scores on general effectiveness questions. Furthermore, groups that met both the 6-Hats and MBTI criteria had the highest scores in each group of questions. Felder[18] and colleagues found that introverts typically outperform extraverts, intuitors outperform sensors, thinkers outperform feelers, and judgers outperform perceivers.

Given these results, more research is needed to quantify the role of personality indicators and temperament on group and individual performance. Specifically, investigating the role of diversity on group dynamics, particularly when there is one temperament making up a majority of an engineering team. Due to the preponderance of Guardians found in some engineering departments, this extreme scenario may be quite likely and have a negative impact on performance, individual retention, and experience.

CE350 – Infrastructure Engineering (3 credit hours)

Course Scope, Objectives, and Structure. The course has five primary objectives:

1. Identify, assess, and explain critical infrastructure components and cross-sector linkages at the national, regional, and municipal levels,
2. Calculate the demand on infrastructure components and systems,
3. Assess the functionality, capacity, and maintainability of infrastructure components and systems,
4. Evaluate infrastructure in the context of military operations, and
5. Prioritize and recommend actions to improve infrastructure resilience

The course is decomposed into five different blocks of instruction. The first presents the general concepts of infrastructure systems through discussions on network theory, infrastructure modeling, and stakeholder analysis. The next few blocks introduce three of the primary infrastructure systems in our society today: water and wastewater, energy, and transportation. The final block orients the students to the military applications of infrastructure engineering. The project, discussed below, is executed at the end of the semester.

Infrastructure Reconnaissance Project and Peer Assessment. The CE350 infrastructure reconnaissance project requires students to conduct a detailed reconnaissance and assessment of a specified location as a potential base of operations in the aftermath of a catastrophic event. The proposed site has existing infrastructure, such as water and wastewater treatment plants, solid waste disposal, and emergency generators. The project groups must apply their knowledge of infrastructure systems and assess the current capacity of the site against the demands of the incoming population. There were 12 total project groups in the course with each group containing 4-5 students. The instructor determined the groups based on both a diversity of temperaments and evenly-distributed GPA.

The project itself has three graded portions. The course instructor provides the groups with the project's scenario, detailed submission requirements, and affords groups over two hours to reconnoiter the proposed site's existing infrastructure. The groups compile a table quantitatively summarizing the capacity and demand of each infrastructure system on site (i.e., water, wastewater, solid waste, electrical power, fuel, transportation, billeting, and security). Furthermore, the groups provide overlays for their proposed site layout to utilize the existing infrastructure. Based on their findings, each group delivers their recommendation on whether or not the site is suitable for the incoming population, as well as feasible design alternatives to address the site's shortcomings. The briefing served as a platform for the group to articulate their findings and recommendations to the instructor. After the briefing, the instructor cross-examines each member of the team to assess their understanding of the overall project.

Upon completion, the students complete a peer assessment on each member of their group. The peer assessment consists of a series of attributes that each group member uses to evaluate their respective peers by means of a ranking system (i.e., 1=strongly agree, 2=agree, 3=disagree, and 4=strongly disagree). The attributes in the peer assessment are:

1. Participated in group discussions
2. Was dependable in attending group meetings
3. Willingly accepted assigned tasks
4. Completed work in a timely manner or made alternative arrangements
5. Helped others with their work when needed
6. Did work accurately and completely
7. Contributed to fair share of overall work load
8. Worked well with other group members
9. Overall was a valuable member of the team

The instructor then tallies the scores for each member of the group. Subsequently, the highest tally in the group represents the *worst-rated* team member. With the overwhelming majority of Guardians represented within the population, the presentation of results below focuses on whether or not a Guardian is quantitatively worst-rated in a particular group. The authors feel that this isolation provides interesting correlations that support the thesis that diversity in temperaments rather than uniformity promotes improved group performance. For the purposes of this paper, the authors define *group interaction* in terms of the biases that may exist between different temperaments, and *group performance* in terms of the group's overall project grade. Ultimately, improved group interaction serves the purpose of improved group performance.

<u>Presentation of Results</u>

In the fall 2016 semester, the CE350 course consisted of 45% civil engineering majors and 55% non-civil engineering majors, with a gender breakdown of 85% male to 15% female. At the beginning of the semester, the instructor had every student complete the Keirsey Temperament Sorter. Guardians were the most-represented temperament at 65%, with Idealists at 22%, Rationals at 7%, and lastly, Artisans at 6%. Civil engineering majors displayed a 72% Guardian representation, while non-civil engineering majors only had 59%. The relationship between gender and temperament coincided with the general population described above – both genders displayed a majority of Guardians, with minority representations of Idealists, Rationals, and Artisans.

For the purposes of the paper, the authors conducted two complementary analyses – first assessing group interaction by means of peer assessment and second, assessing group performance. We dichotomized the groups into two mutually exclusive categories.

1. *Category 1* groups consist of a majority (greater than 50%) of Guardian members, representing more uniform groups. A total of nine project groups with 42 total students fit into this category, of which 30 individuals displayed Guardian temperaments (on average 71.4% of Category 1 consists of Guardians). See Figure 1.

2. *Category 2* groups consist of 50% or less Guardian members, representing more diverse groups. Within the three project groups are 12 total students, of which only five have Guardian temperaments (on average 41.7% of Category 2 consists of Guardians). See Figure 1.

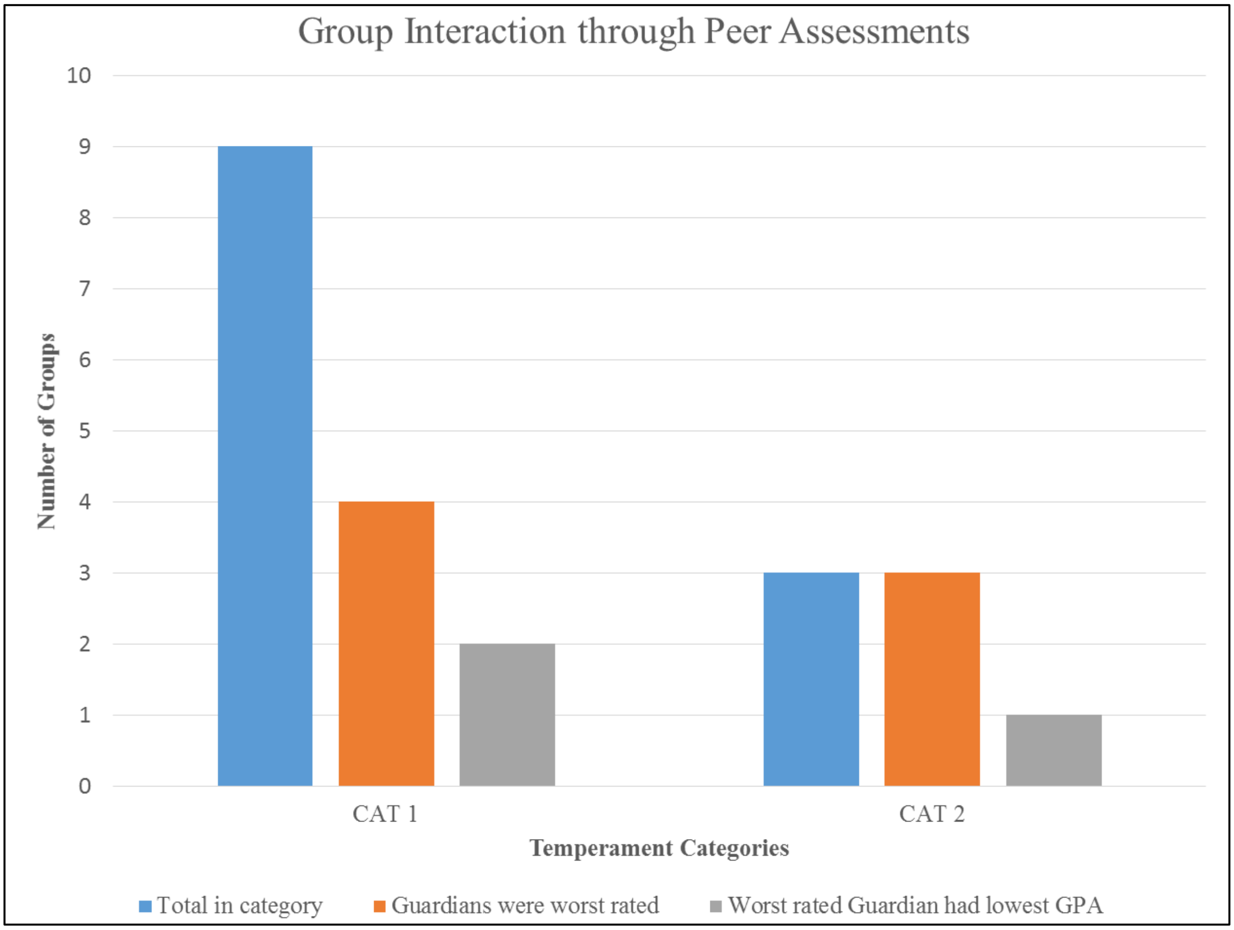

Figure 1: Group Interaction through Peer Assessments

Figure 1 illustrates the total number of groups, along with those groups where a Guardian was rated worst by their peers, and number of groups where a Guardian had the worst GPA. First, the blue bar shows how many groups are in each category for comparison. Next, the orange bar represents the number of groups' peer assessments resulted in a Guardian member being worst-rated. It is beyond the scope of this paper to investigate all the potential variables that may affect the outcome of the peer assessments. However, it may be possible to isolate one other potential cause for the worst-rated member in the group by considering team members' GPA in order to see if it has an effect. Consequently, the third bar in gray, on Figure 1, represents the Guardians quantitatively representing the worst-rated in the group that also had the lowest GPA among team members. In other words, a Guardian receiving the worst rating in a group may have been rated in this manner due to generally poor academic performance rather than temperament.

While Figure 1 considers the group interaction for uniform and diverse project groups, Figure 2 presents the overall group performance of the two categories. This second analysis is again given in terms of the temperament categories established previously. The orange bars represent each category's average project score in terms of the number of standard deviations (in percent) away from the mean course average for the project. Essentially, a positive value illustrates a better performance compared to the average, while negative value represents a score below the mean. The data callouts at the top of each category's score bar is that respective category's average GPA. While the instructor sought to evenly-distribute the representative GPA in each group so that one particular group did not have an apparent academic advantage over another, by happenstance Category 1 has a slightly higher average GPA than Category 2. This disparity and its significance are highlighted in the discussion of results below.

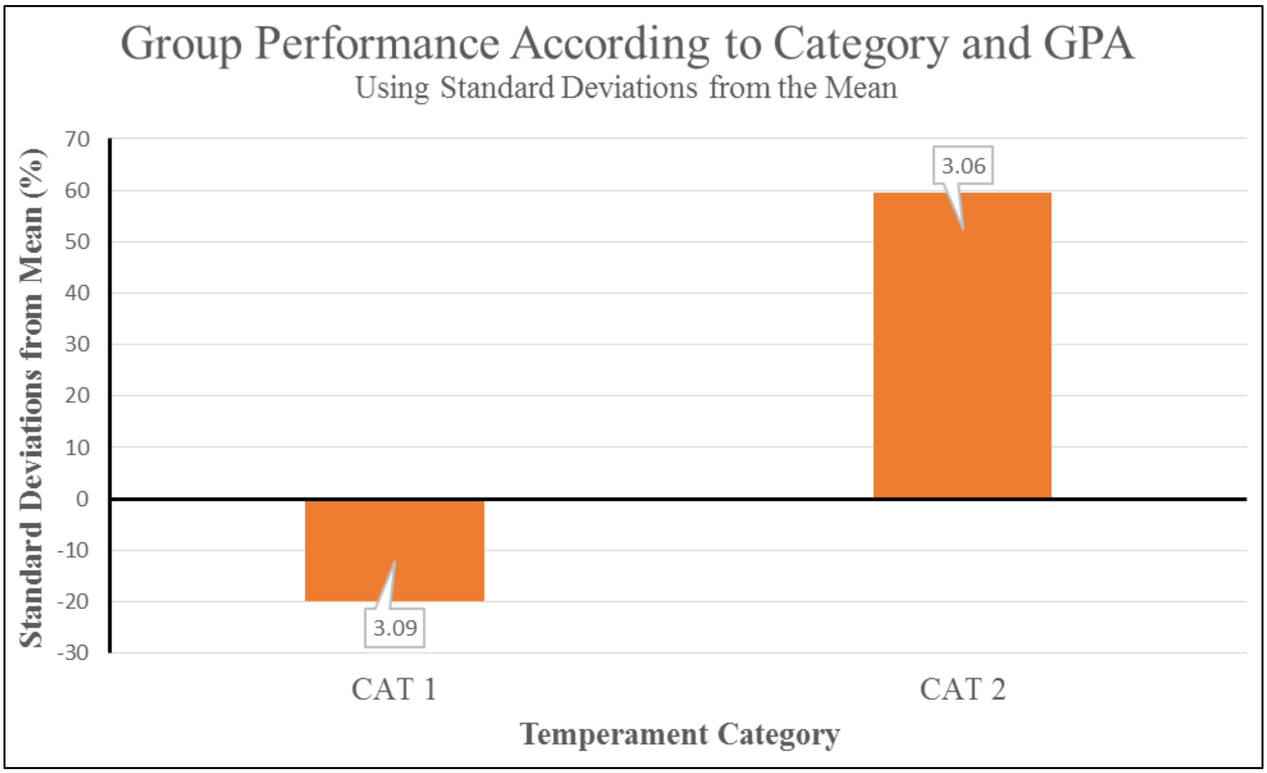

Figure 2: Group Performance According to Category and GPA

<u>Discussion of Results</u>

These data show clear differences between our groups made up of majority guardians (CAT1) and those with more diverse temperaments (CAT2). For Category 1 groups, as shown in Figure 1 above, only four Guardians received the worst-ranking peer assessment in their respective groups (that is less than half, or just over 44%). While on average, over 70% of this category is made up of students with Guardian temperaments. Two of these four occasions may have been due to the worst-rated Guardians having the lowest GPA in their particular group. On the other hand, Category 2 reveals that all three groups identified a Guardian in their group as the worst-ranking on peer assessments. It is even more interesting to see that only one of those three scenarios might have been due to the Guardian having the lowest GPA in the group. Recall from the description above the overall percentage of Guardians within each category. While Category 1 consists of 71.4% Guardians, only 44% of the groups chose a Guardian within their respective group to be the worst-rated despite it being more statistically-likely that a Guardian would be picked. On the other hand, Category 2 consists of only 41.7% Guardians but each group isolated one of the Guardians within their respective groups as the worst-assessed peer. These data suggest that there may be bias within these groups based on temperament distribution, since the peer assessments did not line up with overall distribution, and seem to be more favorable to those in the majority.

These results show that Guardians may tend to prefer working with one another over other temperaments most of the time. On the other hand, as diversity increases and more non-Guardian members are introduced into a group, the isolation of another Guardian is more likely. Essentially, the group dynamic changes. With a larger sample population in future investigations, the authors believe that the mixture of different temperaments within a group would tend toward a more distinct impartiality to individual temperaments.

Also, it is noteworthy that the category that received the highest average grade on the project had a slightly lower average GPA. As can be seen in Figure 2, Category 2 has a marginally lower GPA but performs almost one whole standard deviation better than Category 1 on their respective groups' project submissions. These results, along with the previous group interaction chart (in Figure 1 above), show that average group GPA is not the *primary* driving mechanism for overall group performance. On the other hand, it seems that the interaction of individual temperaments plays a distinguishable role in overall group performance. More specifically, two important observations can be made. First, having a generally uniform temperament population in a particular group seems to lead to the isolation of the minority temperament within the group, but remarkably, it does not lead to optimum group performance. On the contrary, building groups that consist of a diversity of individual temperaments seems to lead to better group interaction and improved relative group performance.

Conclusion

The 54 students in an infrastructure engineering course took the Keirsey Temperament Sorter in the fall semester of 2016 and were divided up into project groups based on their respective temperaments. The course instructor then evaluated their group interaction based on peer assessments and their group performance based on their overall project grades. The purpose of the paper was to show that temperament diversity rather than uniformity promotes improved group performance in a project-based learning experience within a civil engineering course consisting of both majors and non-majors. The sample population of 12 project groups were categorized in terms of their composition of Guardian temperament members (i.e., Category 1 consisted of over 50% while Category 2 consisted of 50% or less). Despite the statistical likelihood otherwise, the results showed that Guardian-majority groups isolated non-Guardian members in their peer assessments (56% of the time out of nine groups), while the diverse groups in Category 2 inevitably rated a Guardian worst in their group (100% of the time out of three groups). Despite the fact that Guardians seemed to prefer working together, Category 1 groups performed nearly a whole standard deviation worse on average than the Category 2 groups. Furthermore, the Category 2 groups outperformed Category 1 groups despite having a slightly lower GPA.

The authors realize that this paper did not address the many other possible factors that affect group interaction and performance, such as learning styles, age, gender, and ethnicity. While there are certainly more factors involved in group dynamics, there does appear to be a strong case establishing that an increase in group performance is driven primarily by temperament diversity rather than overall group GPA. The authors believe that the findings of this paper on the influences of temperament diversity on group interaction and performance will create a platform for continued research in this particular area, where larger sample populations, different group scenarios, and additional evaluation criteria are investigated to further validate the findings of this study.

Bibliography

1. Mills, J. E., & Treagust, D. F. (2003). Engineering education—Is problem-based or project-based learning the answer. *Australasian journal of engineering education, 3*(2), 2-16.
2. Hadim, H. A., & Esche, S. K. (2002). Enhancing the engineering curriculum through project-based learning. *Frontiers in Education*, IEEE.
3. Jackson, S. E. (1992). Consequences of group composition for the interpersonal dynamics of strategic issue processing. *Advances in strategic management*, *8*(3), 345-382.
4. Larochelle, P. (2005). Unifying assessment of freshman design teams with team project management. *Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition, Portland, OR*.
5. Bannerot, R. (2005). Characteristics of good team players. *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition, Annual Conference, Salt Lake City, UT*.
6. Hunkeler, D., & Sharp, J. E. (1997). Assigning functional groups: The influence of group size, academic record, practical experience, and learning style. *Journal of Engineering Education*, *86*(4), 321-332.
7. Lorimer, S., & Elford, E. (2012). StrengthsQuest for engineers. *Proceedings of the 2012 American Society for Engineering Education Annual Conference & Exposition, San Antonio, TX*.
8. Keirsey, D., & Bates, M. M. (1984). Please understand me. Prometheas Nemesis Book Company.
9. Keirsey, D. (1998). Please understand me 2. Prometheas Nemesis Book Company.
10. McCaulley, M. (1990) The MBTI and individual pathways in engineering design. Journal of Engineering Education, 80 (5), 537-542
11. Scott, T. H., Parsons, J. R., & Seat, J. E. (2002). Use of Myers-Briggs Type Indicator in the University of Tennessee ENGAGE Freshman Engineering Program. *Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition, Montreal, Canada.*
12. Freyne, S. F., Gude, V. G., & Truax, D. D. (2016) Civil engineering students' viewpoints on teaching, learning, and careers. *Proceedings of the 2016 American Society for Engineering Education Annual Conference & Exposition, New Orleans, LA.*
13. Racicot, K., & Pezeshki, C. (2007). Active assessment in capstone design using a system approach. *Proceedings of the 2007 American Society for Engineering Education Annual Conference & Exposition, Honolulu, HI.*
14. Dillon, J., & Cheney, J. (2009). Building the team: Assessing two design group formation methodologies. *Proceedings of the 2009 American Society for Engineering Education Annual Conference & Exposition, Austin, TX.*
15. Flora, J. R., & Cooper, A. T. (2005). Incorporating inquiry-based laboratory experiment in undergraduate environmental engineering laboratory. *Journal of Professional Issues in Engineering Education and Practice, 131*(1), 19-25.
16. Bannerot, R. (2005). Characteristics of good teams. *Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition, Annual Conference, Portland, OR.*

17. Jensen, D., Wood, K., & Wood, J. (2003). Enhancing mechanical engineering Curriculum through the use of hands-on activities, interactive multimedia and tools to improve team dynamics. *Int. J. Eng. Educ*, *19*(6), 874-884.
18. Felder, R. M., Felder, G. N., & Dietz, E. J. (2002). The effects of personality type on engineering student performance and attitudes. *Journal of Engineering Education*, 91(1), 3-17.