# AC 2009-1523: BUILDING THE TEAM: ASSESSING TWO DESIGN-GROUP FORMATION METHODOLOGIES

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# Building the Team:
# Assessing Two Design Group Formation Methodologies


## Abstract

Design is a social process. This commonly held concept in the design community is widely supported by research literature. Most universities utilize student teams when teaching the design process to replicate professional practice and provide a structure around which students learn the subject matter. However, a commonly encountered problem with design group formation in an academic environment is the decision by the instructor on how to form the teams. Should students be allowed to choose their own groups, or should instructors assign the teams directly? If groups are assigned, how should the students be divided among the teams? This project seeks to provide insight into these questions.

ME450, a course which provides a capstone design experience to senior non-engineering majors at the U.S. Military Academy at West Point, is structured around three team-based engineering design projects, or EDPs. Student design teams for these EDPs consist of three to four individuals who work toward the common goal of applying the engineering design process to designing and constructing prototypes for competition against the other teams in the course.

To study the results of group formation, student design teams for ME450 were instructor-assigned in half of the sections and self-selected in the others. Prior to the first lesson of the course, all students were required to take the Jung Typology Test ™ based on Carl Jung and Isabel Myers-Briggs typological approach to personality. In those sections with instructor-assigned groups, teams were assembled based on the results of this test with the goal being to place students into groups with varying personality types. This study seeks to provide insight into the following questions:

- Are there any significant differences in student performance between instructor-assigned and self-selected design groups? Which groups produce better products?
- Do individuals of the same or differing personality types come together in the self-selected sections?
- Are students more satisfied with one or the other type of group formation?
- Which groups tend to work best together with the least amount of personal conflicts?

This paper provides a qualitative assessment of the effectiveness of these two group formation methodologies through the use of student grades, course performance, an assessment of the quality of team products and prototypes, surveys, interviews with students, and course-end student feedback. The results of this assessment should be useful to any program that uses student teams to teach engineering.

## Introduction

Project-based learning has been gaining popularity for many years as a method of teaching design to engineering students.[1] Project-based design not only allows students to "experience design as active participants"[1] but also allows them to learn subject matter in an environment that more closely replicates professional practice than other standard classroom activities. Most often, design projects are assigned to teams of students who must work closely together to solve complex problems. Allowing students to work in teams has many benefits, from helping meet ABET general engineering criteria that focus on the social aspects of engineering education, to providing students with an opportunity to learn important teamwork skills that will transfer directly to their future careers.

A common problem for instructors in courses that teach team-based design is deciding how to form effective student design groups. There are many methods available, some of which require more or less preparation than others. Some examples of team-selection methods were presented by Shen et. al. in 2007 and include:

(a) Let the students choose their own teams.
(b) Use the alphabetical class order in the register.
(c) Use the university student number code order.
(d) Select team members based on previous performance.
(e) Select groups based on a heterogeneous mixture, i.e. sex, age, nationality, specialization, etc.
(f) Select a team leader and let them pick one additional member in turn.
(g) Select team members based on sitting or standing position.
(h) Select team members based on astrological 'star sign' or month of birth.
(i) Select team members based on their Personality Type and/or Learning Style.
(j) Issue coded labels to students, who then form groups based on the codes.

According to Shen, the most commonly used are (a), (b), and (c) above.[3] However, several studies suggest other methods, especially (i) above, may produce more effective teams.[3,4,5]

The goal of the research presented in this paper is to compare two of these team-formation methodologies: namely, letting the students choose their own teams (a), and selecting team members based on their personality types (i). Both methodologies were used separately but simultaneously in two different sections of ME450, a senior capstone design course at the United States Military Academy at West Point. This paper provides an assessment of the results.

## The Course

ME450 was developed to provide a capstone design experience to non-engineering majors at the United States Military Academy at West Point. For four years, this course has successfully

presented the mechanical engineering design process to students enrolled in humanities, social sciences, life science and other non-engineering degree programs.[2] The objectives of this course are as follows:

- Design solutions to open-ended problems through an organized design process.
- Improve problem-solving and decision-making abilities.
- Apply basic engineering science to the design of mechanical devices
- Use technological tools to enhance the design process.
- Learn new concepts and technologies without the aid of formal instruction.

In order to inspire this somewhat reluctant student population to get excited about applying engineering principles and problem-solving techniques, the course is structured around three engineering design projects, or EDPs. These projects, which become progressively more complex throughout the semester, require student design teams to take taught theory out of the classroom and apply it to the design of mechanical systems.[2] A brief description of these EDPs is presented below, but they are more thoroughly outlined in previous literature.[2]

The first EDP serves as an introductory design experience and is a self-selected problem which students solve theoretically using the engineering design process taught in class. While the first steps of this EDP are performed individually, students form teams mid-way through the project and complete the EDP using one of their team members' initial problems. Students are required to submit a written report and give a graded oral presentation at the end of this and each of the following EDPs.

In the second EDP, students must design, construct and compete with a water rocket. Students utilize the design process a second time, but must incorporate new theory and calculations concerning thrust, drag and aerodynamic stability. Students also must build and test prototypes during this EDP. The final competition pits the student teams against one another as they try to hit a target 50 meters away.

The third and final EDP consists of the design and construction of a LEGO™ remote control vehicle. Once again, the student design teams must apply the design process and incorporate additional theory, in this case torque, power, gear trains and other vehicle-related concepts. The final competition serves as the course term-end exam and generates a great deal of excitement among the students.

Midway through the first EDP, students are assigned to their design teams. Students maintain these same teams throughout the entire one-semester course. During the semester studied in this paper, there were a total of 31 students enrolled in ME450. These students were split across two sections which met during different hours on the same day. Both sections had the same instructor and used the same classroom. For the duration of this paper, the two sections will be referred to by their hour designations, B Hour and C Hour. The B Hour class had 15 students and the C Hour class had 16 students. Each class was broken down into five design teams

containing three or four members each. The B Hour design teams were instructor-assigned based on personality types, while the C Hour students were allowed to select their own partners. All other course requirements, instruction, and tests remained the same for both sections.

**The Approach**

Prior to arriving for the first day of class, all students were required to complete a no-cost on-line "Jung Typology Test™" based on Carl Jung and Isabel Myers-Briggs typological approach to personality.[6] While this is not the better-known Myers-Briggs Type Indicator, MBTI®, this test is closely based on the same concepts and consists of 72 Yes-No questions which gave each student the same four-letter personality type score that is produced by the MBTI.

Various forms of the MBTI, like the Jung Typology Test™ used in this experiment, have been used with great success to help select design teams in both academic and professional environments. Douglass Wilde, a Research Professor at Stanford University, has been using tests based on the principles of the MBTI and Jungian personality theory to build engineering design teams for over 20 years.[4] In 2004, Wilde reported that his use of personality types to select teams resulted in nearly a tripling of student design teams winning prizes in an independently-judged national design competition. The MBTI has been in use in various forms for over 60 years.[3] "No other psychological testing instrument has been subjected to as many tests of reliability and validity."[7]

Both the MBTI and the Jung Typology Test™ used for ME450 share the following four dichotomies as seen in the chart below from Shen et. al. The interaction of these dichotomies gives 16 individual personality types, each consisting of four letters (ENTP, ISFJ, etc).[3]

| | | | | |
|---|---|---|---|---|
| Meyers-Briggs | Extroversion | E | Introversion | I |
| | Sensing | S | iNtuition | N |
| | Thinking | T | Feeling | F |
| | Judging | J | Perceiving | P |

Jung

**Figure 1: Four Dichotomies as outlined by Shen et. al.[3]**

The primary purpose of using personality tests in the formation of design teams is to increase the "variety of creative roles"[4] on each team and thereby enhance the team's ability to effectively solve problems and do work. Therefore, the goal of the instructor when forming teams in ME450 was to place members of varying personality types onto the same team. The instructor assigned design teams for the B Hour section of ME450 using the results of the Jung Typology Test™. Students were broken down as best as possible into design teams based on the following personality type quadrants excerpted from "Please Understand Me II: Temperament, Character, Intelligence" by David Keirsey.[8]

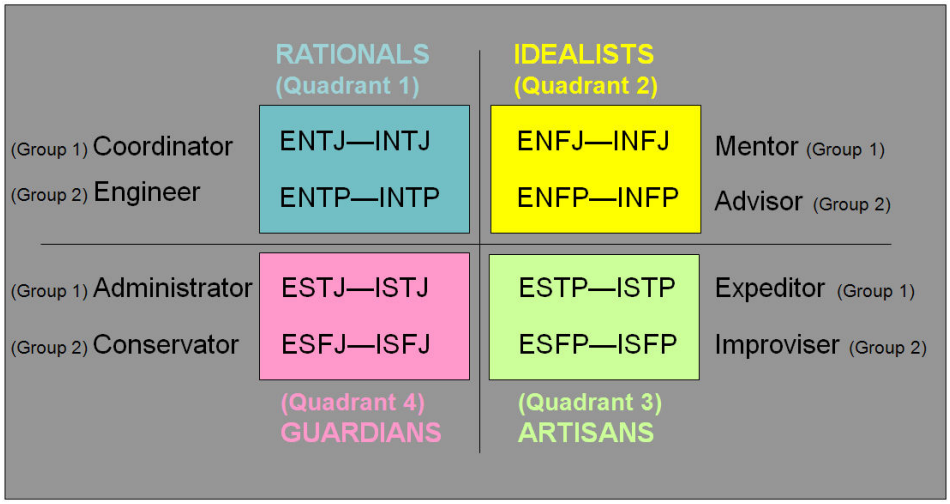


**Figure 2: Personality Type Quadrants**

For ease of use, the quadrants were numbered from one to four starting with the "Rationals" quadrant in the top left corner and working clockwise. Then, within each quadrant, the groups were numbered with one for the top group and two for the bottom group. In this manner, both ENTJs and INTJs would be considered Quadrant 1, Group 1, while ESFPs and ISFPs would be considered a Quadrant 3, Group 2, etc. This information was entered into a spreadsheet for each student in the class. The students were then grouped by quadrant, trying to obtain the maximum diversity in personality types in each design team. No other data about the students (GPA, sex, age, etc) was taken into consideration. Of course, with only 15 students in the section, there was some degree of overlap as can be seen in the figure below:

**B HOUR**
**CARE BEARS**

| Team Name | Personality Types | Quadrant | Group |
|---|---|---|---|
| The Scallywags | ENTJ | 1 | 1 |
| | ENFJ | 2 | 1 |
| | ISFJ | 4 | 2 |
| The Infidels | ENTJ | 1 | 1 |
| | ESFP | 3 | 2 |
| | ISTJ | 4 | 1 |
| Team Slacker | INTJ | 1 | 1 |
| | ISTJ | 4 | 1 |
| | ISTJ | 4 | 1 |
| The Breakfast Club | INTJ | 1 | 1 |
| | ENFJ | 2 | 1 |
| | ESFJ | 4 | 2 |
| Orange Iguanas | ENTP | 1 | 2 |
| | ENTJ | 1 | 1 |
| | ISFJ | 4 | 2 |

**Figure 3: B Hour, Instructor-Assigned, Personality-Based Teams**

Additionally, one student failed to turn in his personality type until after the groups were formed. This resulted in two students of the exact same personality type being on the same team. Interestingly enough, this team, "Team Slacker," had by far the most personal conflicts of any other team in both sections as will be discussed later.

The students in the C Hour class were allowed to choose their own partners. Based on the fact that this section had 16 students, there was one four-person design team. Their personality types can be seen below:

| C Hour<br>FIGHTING BADGERS | | | |
|---|---|---|---|
| **Team Name** | **Personality Type** | **Quadrant** | **Group** |
| Team Taxista | ESFJ | 4 | 2 |
| | ESTJ | 4 | 1 |
| | ESFP | 3 | 2 |
| Team Platanos | ISTJ | 4 | 1 |
| | ENTJ | 1 | 1 |
| | ENTJ | 1 | 1 |
| The Peloponnesian League | ENTJ | 1 | 1 |
| | ENFJ | 2 | 1 |
| | ISTJ | 4 | 1 |
| | ESFJ | 4 | 2 |
| Sweetness | INTJ | 1 | 1 |
| | INFJ | 2 | 1 |
| | ESTJ | 4 | 1 |
| Lead Farmers | ISTJ | 4 | 1 |
| | INTJ | 1 | 1 |
| | ENFJ | 2 | 1 |

**Figure 4: C Hour, Self-Selected Teams**

There do not seem to be any trends in the personality types of the self-selected teams. Three teams have more than one member from the same quadrant, but overall, it seems that students of like personality types did not necessarily group together nor avoid one another.

Beyond this difference in design team formation, all other aspects of the course remained the same for both sections. Students were not informed of this difference between the two sections until the end of the semester. As the semester progressed and students worked on the EDPs, several data points were gathered to assess group performance. These included student grades, a short survey at mid-semester, prototype performance on EDPs 2 and 3, instructor observations, informal interviews with students, a daily student time survey, as well as an end-of-course survey. The results of this data are discussed in the following section.

## The Results

The results of this experiment were very interesting. The small sample size prohibited an effective statistical analysis, but some definite trends began emerging upon analyzing the data. First, there was no large discrepancy in final grades between the two sections. Both groups of students received similar grades on both individual and group requirements as can be seen below:

| B Hour | C Hour |
|---|---|
| Instructor-Assigned Teams | Self-Selected Teams |
| **Individual Grades**<br>88.43% std 5.48% | **Individual Grades**<br>89.81% std 5.26% |
| **Group Grades**<br>91.82% std 7.26% | **Group Grades**<br>89.95% std 10.02% |

**Figure 5: Section Course Grade Comparison**

Students from both sections also gave similar answers to several end-of-course survey questions, especially those having to do with the instructor's performance as well as their ability to function professionally in the future. USMA Course-End Feedback is collected using a 5-point scale. Students respond to survey statements by assigning values from 1: Strongly Disagree to 5: Strongly Agree.[2] While the results were anonymous, the data could be analyzed by section. Some of the results that were similar for both sections are shown below:

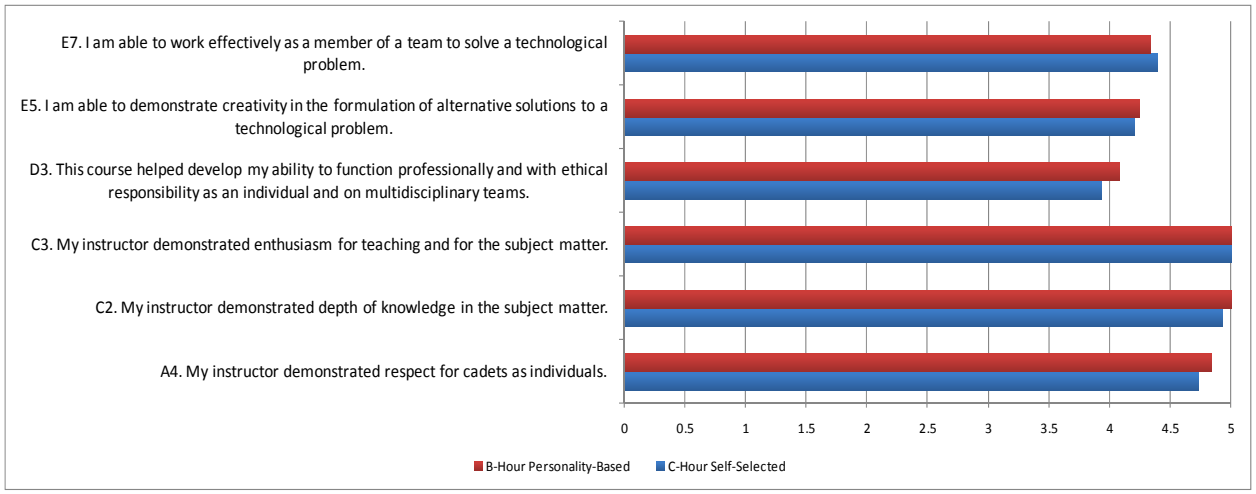


**Figure 6: End-of-course survey questions with similar results for both sections**

However, there were also important differences observed between the sections. During EDPs 2 and 3, when the teams were required to design and build prototypes in order to compete against each other, the personality-based teams outperformed the self-selected teams, on average. For example, during the record water rocket launch for EDP 2, the students were graded on the length of time their rockets stayed in the air as well as their accuracy at hitting a target 50 meters

away. The B Hour personality-based teams outperformed the C Hour self-selected teams in both hang time and accuracy (as measured by the average distance their rockets landed from the target) as can be seen below:

| B Hour | C Hour |
|---|---|
| Instructor-Assigned Teams | Self-Selected Teams |
| **Avg Rocket Hang Time**<br>6.20 s | **Avg Rocket Hang Time**<br>5.82 s |
| **Avg Distance to Target**<br>47.8 ft | **Avg Distance to Target**<br>60.6 ft |

**Figure 7: Section Performance on EDP 2**

The personality-based teams also outperformed the self-selected teams in the final LEGO™ vehicle competition for EDP 3. The final tournament had vehicles from both sections competing against one another in a head-to-head double-elimination competition. The vehicles were required to pick up and deposit balls in various locations in order to earn points. The B Hour instructor-assigned personality-based teams clearly outperformed the C Hour self-selected teams in this competition with four of the top five places, including first and second place, going to personality-based teams. This superior performance in winning competitions by the personality-based teams echoes the results achieved by Wilde at Stanford.[4]

Another important difference between the two sections had to do with personality conflicts. A mid-semester survey asked *"Are you satisfied with your design group thus far? Is being in a group a help or a hindrance on the EDP? Why?"* 27 students from both sections responded, with the results across both sections being 67% positive, 14.8% Negative, and 18.5% Neutral. One of the negative responses came from 'Team Slacker,' a B-Hour personality-based team that later had a near-breakdown with the INTJ personality-type student becoming extremely frustrated with his two ISTJ partners. Responding to the mid-semester survey, the INTJ member of the team responded:

> *I am not really satisfied with my design group. They seem to lack motivation and it often falls on me to organize the group and even to do the work.... I feel like if it were not for me nothing would be done. The group is only a help in that I don't have to do everything by myself (which isn't even always the case).*

As the course progressed, it became clear to the instructor that the B-Hour sections were actually having more personality conflicts than the self-selected C-Hour groups. This may have been due to the fact that the self-selected teams in C-Hour tended to already know each other and therefore got along better, but this was surprising given that the personality-based teams were producing better products.

The 'Team Slacker' conflict was particularly troubling. The instructor intervened on more than one occasion to ensure that the group was continuing to function. This conflict very well may

have been because there were two of the same personality types on the same team, but the problem was not between the two ISTJs, but rather between the INTJ and the two ISTJ team members. Interestingly enough however, for all their disagreements, Team Slacker performed well in both EDP competitions, producing good prototypes in each case and finishing second out of 10 teams on EDP 2 and fifth on the final EDP 3 competition.

Other groups also suffered from internal conflict, based on instructor observations and end-of-course survey results, especially in the personality-based section. This was confirmed by the end-of-course survey which revealed the following about the students' perceptions of the performance of their design teams:

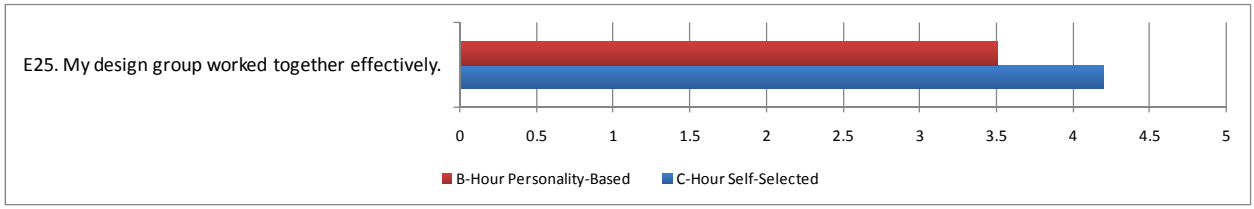


**Figure 8: In general, Personality-Based Teams did not feel that they worked together as well as Self-Selected Teams**

Clearly, the B-Hour personality-based teams felt that their design groups worked less effectively together. Additionally, the biggest discrepancy between the responses to the end-of-course survey was to the following question:

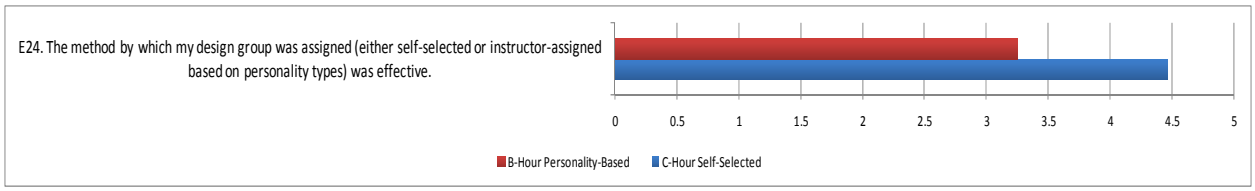


**Figure 9: Self-Selected Teams were more positive about their group-selection methodology**

It is obvious from these results that the B-Hour students were, on average, less-than-pleased with having their design groups assigned.

The group assignments also appear to have had some impact on how the students perceived the course as a whole. As mentioned before, there were no other changes to the course between the two sections besides the method of group selection, but the students in the personality-based teams had a less-positive assessment of their ability to apply the engineering design process than the self-selected teams. They also did not feel as strongly that the course increased their motivation to continue learning:

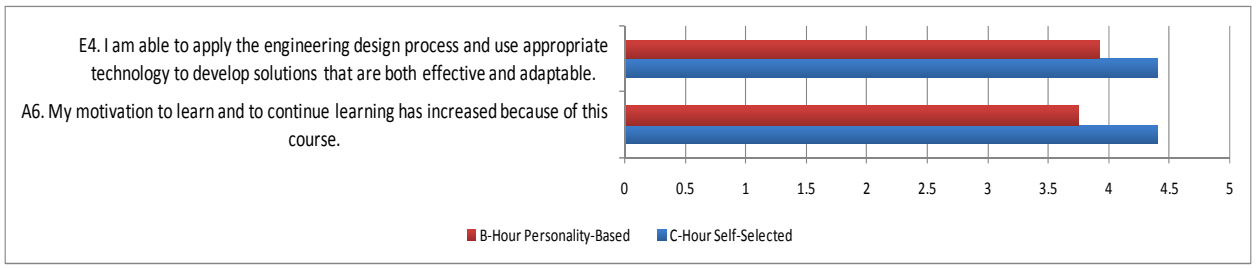


**Figure 10: Group Assignment appears to have had an impact on how students perceived the results of the course**

Additionally, the length of time that the students felt they spent completing their assignments also seemed to be influenced.

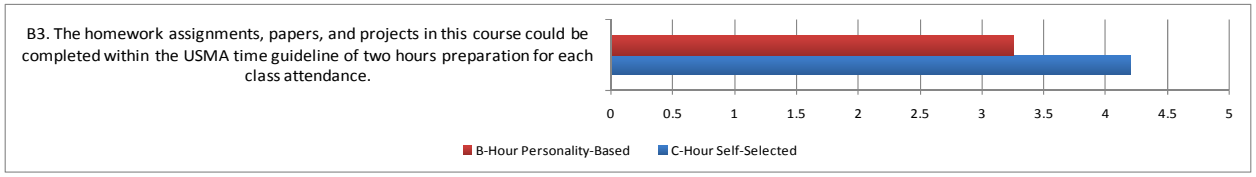


**Figure 11: Personality-Based Teams felt they spent more time on assignments**

However, this assessment of time spent is not backed up by daily time-survey data that was collected from students on the time they spent preparing for each class. This time survey data contradicts the students' assessment of time spent on each assignment. The time survey data shows that personality-based teams actually spent *less* time preparing for class than the self-selected teams with an average of 51.46 minutes per lesson while the self-selected teams spent an average of 61.31 minutes per lesson. Based on this end-of-course survey and instructor observations, the students in the B Hour instructor-assigned groups had a slightly more negative outlook about the class. This very well may have been a result of personal conflicts within their design groups.

Finally, the end-of-course survey asked students to "Please provide feedback on how your design group was selected and how it performed as a result." For the personality-based design teams in B Hour, the responses were 50% Positive, 33% Negative, and 17% Neutral, while the self-selected teams' responses from C Hour were 73% Positive, 20% Negative, and 7% Neutral. Examples of both positive and negative responses from each section are given below:

**B-Hour Personality-Based Section:**

Positive:

> *"Our design group was based upon linking up different personality profile types in an effort to get three different complementary types to work on something. In our case, we got one member who enjoyed building, one who preferred the math aspects, and one sort of in-between person, so it all worked out rather well."*

*"It was selected based on learning styles, and this was a good thing. Each of us had a specific ability, be it calculations, writing, design, craftsmanship, that we were able to contribute."*

Negative:

*"My group was terrible!!! Those two … are truly pathetic, lazy, and incapable."*

*"It was difficult because one person was good at the material so they would be the one who usually did all the work."*

**C-Hour Self-Selected Section:**

Positive:

*"I picked one of the members who I had worked with in previous classes. My group worked very well together and divided up the project load evenly."*

*"Our group was self-selected and we performed/worked very well together as a result. I already knew both my teammates from previous mech classes, and I knew that they were both intelligent and hard-workers. I knew together we would be very successful, which is what happened. Also, they lived close, which was a bonus.*

Negative:

*"It was selected by students that had shared class before in the class. This created problems toward the end of the semester with an incident where one group member did barely [any] work for an entire project but was still given a good grade."*

*"We chose each other since we had worked with each other in the past. I felt like we were each assigned a part of the project that we usually get assigned and we were not able to diversify what we usually contribute to a group ecercise[sic]. Groups should be chosen by the instructor next time.*

**Conclusions**

This small-scale experiment has shown that using personality types to aid in the creation of design groups can be highly effective, especially in building teams who design superior products. However, this type of group-formation methodology, at least in the case of this research project, led to an increased occurrence of personality conflicts and dissention within design teams when compared to student-selected teams. This conflict, in-turn, had some negative effect on how students perceived the course. Obviously, however, the small size of this experiment makes it difficult to draw any definite conclusions. Additional research will be necessary to allow for a thorough statistical analysis and increase the significance of any results.

## Recommendations

The benefit of using a personality-based approach to team formation is that it will ideally increase the "creative roles"[4] available within design teams, thereby making them well-rounded and more capable of solving complex problems. A disadvantage of this methodology is that assigning students to teams gives them a point of contention with the instructor since they have no say-so in how their teams are formed and may increase personal conflicts within teams as shown here. Allowing students to select their own teams removes this point of contention and may reduce personal conflicts, but also eliminates the benefits gained through the use of personality types.

Based on the results of this experiment, it is recommended that a hybrid of the two team-formation methodologies outlined in this paper be applied in an attempt to obtain the positives of both methodologies and reduce their negatives. Students should be required to complete a personality test, similar to the one used in this experiment. Then, based on the results of the test, students should be allowed to choose their own teammates with the stipulation that they must attempt to cover all four quadrants (Rationals, Idealists, Artisans, and Guardians)[8] outlined earlier and that no team may have two members of the same personality type. The instructor may stipulate that all teams are subject to change if they do not comply with the guidance or offer some other bonus system to encourage students to follow the rules.

This type of approach to group formation would help gain the performance benefits of using varied personality types in each design group while still giving students some say-so in their team makeup. Allowing students to choose their partners also has the benefit of students working out many other unknowns that are not covered by the personality test (who lives close to whom, whose schedules match up best for team meetings, etc). Additionally, although allowing some degree of self-selection certainly will not eliminate personal conflicts within teams, it may serve to reduce them. It would also potentially increase student acceptance of their teams since they have a hand in their creation.

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