

A New Theory for the Assignment of Members to Engineering Design Teams

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Abstract

This paper describes a new theory for assigning members to engineering design teams. In most design classes at the university level, design teams are self-selected or randomly assigned by the instructor. Often this ad hoc approach to design team selection results in ineffectual or dysfunctional teams, which can adversely affect the quality of the product produced by the team. Some researchers have perceived a link between personality type and team performance, and have accordingly suggested the use of various personality tests, such as the Myers-Briggs Type Indicator (MBTI), as a tool for design team selection. To date, however, there has been no working theory as to how different personality types should be assigned to teams, except to strive for "diversity." This paper describes a theory for predicting a team's success based on a new personality profile adapted from the writings of a 19th century philosopher named C.S. Peirce. A new survey instrument is introduced, and preliminary results are presented.

I. Introduction

Most of the engineering work done today is done by teams, rather than by individuals working alone, so part of the mandate of an engineering school is to teach students to work well in teams. In response to this mandate, most engineering programs include one or more classes where a team design project is a major component. Unfortunately, many teams, whether at the university or in industry, experience interpersonal conflict to an extent that detracts markedly from the productivity of the team. In order to minimize such conflict, a manager would like to have a tool that could divide existing personnel into teams, and assign roles to members within each team for maximum productivity. Existing personality tests have been used in this capacity with limited success. As a first step toward a more useful tool for design team selection, the purpose of this study was to: 1) develop a new theory of personality, 2) develop appropriate survey instruments to implement the theory, and 3) perform some initial testing to gain experience with the personality survey and to see if the proposed personality theory is useful for explaining the conflicts that arose naturally within the existing design teams, and to diagnose the failures and to explain the successes of those teams.

II. Background

There are a variety of personality tests available. Generally they fall into one of two types: 1) those that are based on an empirical observation that human personalities can be categorized by

listing certain characteristic traits for each group, and 2) those that are based on some underlying theory that predicts that human personalities *should* fall into certain categories defined by the theory. One popular example of the first type is "The Color Code" proposed by Hartman¹. Hartman proposes four categories (Red, Blue, White, and Yellow), which are defined by a list of traits found in his book. Part of the reason for the success of Hartman's book has been the fact that he goes beyond simply identifying personality types to suggesting how each type can best get along with people of other types. An example of the second type is the Myers-Briggs Type Indicator (MBTI)². Based on the theories proposed in the 1920's by Carl Jung, the MBTI sorts personalities into 16 categories according to a person's preferences for one or the other of four characteristics: Extroversion or Introversion (E or I), Sensing or Intuiting perception (S or N), Thinking or Feeling judgment (T or F), and Judging or Perceiving orientation to the world (J or P). This allows a person's psychological temperament to be characterized by a four-letter code, such as ESTJ or INFP.

This section will review the literature regarding the use of personality tests in engineering design classes. Following that, a brief introduction to Peircian philosophy will be presented in order for the reader to understand the basis for the new personality profile being proposed.

In the past, various researchers have administered personality tests to engineering students for one or more of the following reasons: 1) to study the personality types of engineering students relative to some other population, 2) to foster discussion of how to avoid conflict when working on team projects, and 3) to assign members to teams or assign roles to team members in such a way as to promote teamwork and minimize conflict. This section will describe some previous efforts involving personality type and engineering design teams.

Bannerot³ has compared the personality types of Mechanical Engineering students at the University of Houston to published personality type norms for the general population, engineering students as a whole, and mechanical engineering students as a whole. His results showed that the Mechanical Engineering students at the University of Houston have produced consistent results over a five year period that are significantly different than the previously published norms. The author only uses the personality tests to foster discussion about the best way to interact with others, and does not use the results of the tests to form design teams.

Hunkeler and Sharp⁴ conducted a four year project in order to evaluate the influences on group laboratory performance of: group size, gender, GPA, and learning style distribution, as measured by the Kolb Learning Style Inventory (LSI). The study notes several trends, although only one was statistically meaningful. That conclusion is that four person teams performed better than three person teams. Other rather intuitive conclusions were that it helped to have at least one academically gifted member on the team, and similarly, that it helped to have at least one person who "had good hands" to work the laboratory equipment. With regard to LSI, the overall distribution of the sample of Chemical Engineering students was 6% Type 1 (divergers), 42% Type 2 (assimilators), 42% Type 3 (convergers), and 10% Type 4 (accommodators). Because of the low numbers of Type 1 and Type 4 engineering students, a proper experimental design to determine the ideal mix of types was not possible. As a result, no really statistically significant results were obtained. However, the trends did show that heterogeneous groups did better than homogenous groups, and that mixed Type 2/3 groups did better than average.

Gregory⁵ attempts to map career types (Realistic, Investigative, Artistic, Social, Enterprising, and Conventional) as defined by Holland (cites 4 references) to the four main preferences indicated by the MBTI (thinking, feeling, sensing, and intuitive). Thus, although this work does not focus on teams per se, if one thought of a team as a collection of members with different careers, this work could provide a guide to placing individuals into the different career types needed for the team. It does not give any insight into what career types are needed on an engineering design team.

Magleby and Sorensen⁶ describe a senior design projects course in which teams of approximately five students are formed with an attempt to gain as much diversity of personality on each team as possible using the Hermann Brain Dominance Test, GPA, CAD experience, shop experience, interests, and work experience. Team leadership rotated first semester, then leader selected by instructors with input from students in second semester.

Emmanuel and Worthington⁷ describe the use of three different methods for assigning three-member design teams: 1) on the basis of factors such as interests, academic strengths, and desired teammates, 2) on the basis of the MBTI, and 3) on the factors described in 1 above, with conflict resolution being guided by the MBTI. The paper does not give the mapping they used to map the personality types identified by the MBTI and the roles to be filled on the design team. The authors report that the teams formed using the MBTI did *not* show an improvement in the amount of interpersonal conflict that occurred between members of those teams. Two possible explanations come readily to mind. One possibility is that the MBTI did not accurately type the students for some reason, and the other possibility is that the mapping between MBTI personality types and team membership (and to roles within that team) was somehow flawed. The authors hint that there might have been a little bit of both types of problem present in their study. Addressing the source of the conflicts, the authors state, "Rather than the students being themselves, they tried to conform to the role identified by the MBTI." This sentence seems to indicate that there was a perceived gap between the "self" of the student and the "role identified by the MBTI." The authors continue, "For example, students identified as "leaders" assumed that they must become the group leaders. Those who were identified as "followers" were reluctant to take on leadership roles. The end result was that team members tended to respond as MBTI indicated that they should, rather than the way they felt most appropriate to the situation."

In summary, a variety of psychological tests have been administered to engineering students. They have been quite successful as a means to compare engineering students to one another and to other sample populations. Personality profiles, of whatever sort, have also been useful as a means of promoting greater tolerance and understanding among team members in an effort to reduce internal conflict. Positive results have not yet been demonstrated in the effort to use personality tests as a way to assign members to design teams, although it seems intuitively obvious that some advantage might be gained. This lack of positive results might be due to deficiencies in the personality tests themselves, or to the mappings between personality type and team membership (and to roles within the team).

Introduction of Peircian Philosophy

Max H. Fisch⁸ had the following to say about C. S. Peirce, the 19th century philosopher whose work inspired the theory of personality proposed below. "Who is the most original and the most versatile intellect that the Americas have so far produced? The answer "Charles S. Peirce" is uncontested, because any second would be so far behind as not to be worth nominating. [He was] mathematician, astronomer, chemist, geodesist, surveyor, cartographer, metrologist, spectroscopist, engineer, inventor; psychologist, philologist, lexicographer, historian of science, mathematical economist, lifelong student of medicine; book reviewer, dramatist, actor, short story writer; phenomenologist, semiotician, logician, rhetorician and metaphysician."

Clearly, Peirce was a man with many interests, and one of them was to create a "New List of Categories⁹," that could be used to categorize virtually anything one could imagine. He achieved this by specifying a triadic system of conceptual categories consisting of an indivisible First; which he calls a "reference to a ground," or a pure abstraction; a bi-divisible Second, which is correlated to the First by contrast or agreement; and a tri-divisible Third which is a mediating representation, or interpreter that relates to both the First and the Second. If the three basic categories are insufficient to categorize the item of interest, then the three basic categories can sub-divide in a fractal-like pattern as many times as needed to obtain the number of categories and the level of specificity needed, as shown in Figure 1 below. Notice that when the categories divide, nodes are added along the edges of the triangle that is expanding, and the fractal pattern begins to emerge with a smaller triangle being formed in the lower right corner of the larger triangle. The three nodes of this smaller triangle have the exact same logical relationship to each other as the three nodes of the larger triangle. In the next expansion only the smaller triangle will participate, with nodes being added along its edges, and with a still smaller triangle being formed in the lower right-hand corner.

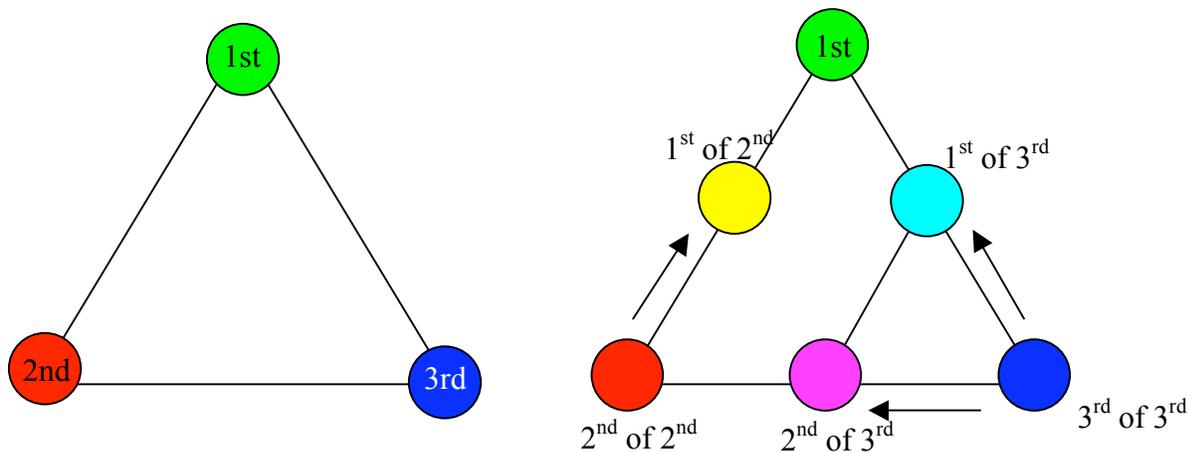


Figure 1 - Basic Peircian Categories and Peircian Categories After First Division

This triadic conceptualization is embedded in virtually all of Peirce's writings, no matter what subject he is addressing, so presumably he would have believed he could categorize personality types using this same scheme, but nowhere is it recorded that he did so. He did, however, describe the three states of mind that a person might be in at any given time¹⁰, namely: 1)

qualitative perception or Feeling, 2) physical action or Reaction to a collision of conflicting feelings, or 3) Thinking, an evolutionary process which mediates between our feelings and our actions.

III. Procedure

For this study, a theory of personality based on the writings of C. S. Peirce was developed that resulted in the identification of seven unique personality types. A survey instrument was created to identify a person's personality type, and a scoring system to interpret the results of the personality surveys was designed. Another survey instrument was also created to measure team function, and to identify the roles assumed by each member of a team. The two surveys were administered to a senior design class and to two sections of a freshman design class at the end of one semester. This section will now describe each of these steps in more detail.

Theory of Personality

In keeping with the spirit of Peirce's philosophy, we have defined our three basic personality types to reflect the natural preference of a person to either feel, act, or think. These personality types are called Type 1, Type 2, and Type 3, respectively. However, we also recognize that more than three categories are needed, so we employ all six nodes of the first Peircian expansion, plus the first node of the second expansion to give us seven categories in all, as shown in Figure 2 below.

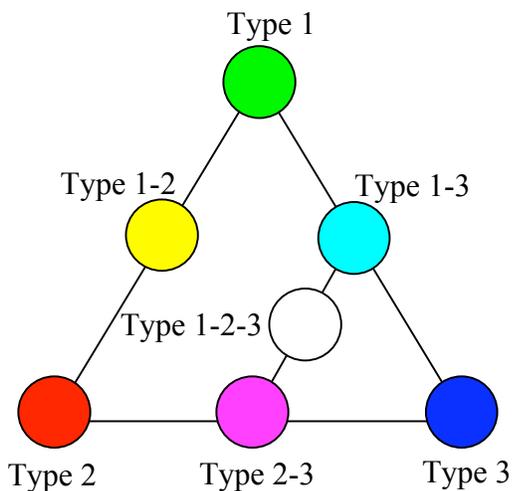


Figure 2 - Seven Peircian Personality Types

There are several things that Figure 2 can tell us about the different personality types, given that the three basic types refer to a preference for feeling, acting, and thinking, respectively. For example, a Type 1-2 personality would have a tendency to want to *act* on whatever *felt* like the right thing to do. By contrast, a Type 2-3 personality would prefer to *act* according to some well *reasoned* rule or authoritative policy. A short description of each personality type and the role that that type of person might be best suited to adopt on a design team is given below.

Type 1, "The Innovator"

The Type 1 person is very perceptive and in touch with his or her feelings. This type of person is so acutely aware that the morning of each day is full of options, that they are sometimes paralyzed by indecision because they are reluctant to select one option over another. Type 1's do not resist authority, but they sometimes try to avoid authority. They seek wholeness and unity rather than division and conflict. Thus, they also compulsively organize their environment into an aesthetically pleasing whole. Such people have a childlike quality about them; they are inclined to be artists or poets. They often have wonderful extemporaneous speaking skills, although their presentation may sometimes be a little disorganized. If they are extremely bright, such people may be scientists or engineers but they are the kind often cut across traditional boundaries and synthesize diverse fields in new, creative ways.

On a design team, the Type 1st personality will typically be the major source of innovative ideas, since they will likely see new connections and possibilities in old procedures and paradigms. Most of their ideas will not be sound; but some will be, and it is the responsibility of other members of the team to select and refine the most promising possibilities suggested by the Type 1st.

Type 2, "The Worker"

This type of person prefers to be actively working, but such people rarely sit back and "decide" what to do. Rather, they work on whatever they feel compelled to do by their physical circumstances, or by some external authority, or by a compulsive need to rebel against some external authority. Such people often seek out conflict. They usually enjoy sports but do not see them as play but rather as a deadly serious business. Such people are commonly found in the military, from the lowest to the highest ranks. If they are extremely bright, they may become successful businessmen who accumulate money and possessions as concrete manifestations of their accomplishments. Scientists or engineers of this type are very practical and task oriented--they want concrete physical results to emerge from their work as soon as possible.

On a design team, the Type 2nd personality would typically be in charge of fabrication if he or she has sufficient hands-on experience. This person might also be used to perform routine or repetitive analysis tasks. They will be in the best position to criticize many of the Type 1st suggestions as impractical or unworkable, but they will take the instructions of the team leader and make them work through sheer force of will and determination.

Type 3, "The Designer"

Type 3 personalities have a natural inclination to think and to ponder. They naturally develop a set of governing principles that mediates between how they feel and how they must act. Such people may question authority initially, but they neither resist nor obey authority compulsively. Instead, they provisionally accept authorities that have proven reliable. When conflicts arise, Type 3rds seek to resolve them to the satisfaction of both parties but they will resist any compromise of their time-tested principles for the sake of some expedient, temporary solution.

Such people are frequently found in public service professions; if they are sufficiently intelligent, they are commonly academics, engineers and scientists.

The process of design usually involves making difficult compromises between competing objectives, which is a natural strength for a type 3, as long as time is not a factor. Therefore, on a design team, the Type 3 personality will be the one best equipped to fill the role of the designer and to reason out a sound basis for making such critical design decisions. When there are only three members on the team, the Type 3rd personality will also often serve as the team leader. Type 3s can make good leaders, but they need to make a deliberate effort to not over-analyze situations that call for immediate action.

Type 1-2, "The Leader"

This type of person could be described as creative and action oriented, but not particularly thoughtful. The Type 1-2s prefer to make decisions and act quickly based on their keen intuition and their perception of the current practical need, rather than on a lengthy study or debate. On the positive side, this ability to quickly make difficult and sometimes brilliant decisions is what makes other people willing to follow a Type 1-2 personality to the ends of the earth. Occasionally, however, a lack of foresight and planning will cause the Type 1-2 trouble that could have otherwise been avoided. In situations where the Type 1-2 personality is unable to rise to a position of leadership, the Type 1-2 will sometimes seek celebrity status instead, and seek converts to their cause by rhetorical persuasion. Such people heavily populate the journalism and entertainment industries. In business they gravitate toward the founding of personality-driven entrepreneurs. Engineers and scientists of this type usually seek out supervisory, management, or sales positions.

On a design team, the 1st of 2nd personality will likely seek the position of team leader, but could also serve effectively as the spokesperson for the group or in sales and marketing. In either case, the 1st of 2nd will likely have the best intuitive grasp of the value of the Type 1st member's creative proposals. That is, the 1st of 2nd will sense that some ideas will "sell" and some won't, and serves to lead the group into further discussion and refinement of ideas with selling potential.

Type 2-3, "The Inspector"

This type could be described as thoughtful and active, but not particularly creative. Type 2-3s prefers to act and make decisions based on a set of well-reasoned principles that have been codified into authoritative policies and procedures. The Type 2-3 is more likely than the other types to accept authority figures, and to have a sincere desire that things should be done "right," which to their point of view means that things should be done, "by the book."

On a design team, this person would be best suited to the roles of product testing, reliability, or quality control. This type may occasionally seek the role of team leader; not for personal gain or glory, but simply to make sure that the project is done properly. If a Type 2-3 does become the leader he or she will have a strong tendency to micromanage the operation. Also, the Type 2-3 personality needs to be careful not to alienate or offend the other team members when work that

is performed is not initially up to the exacting standards of the Type 2-3. The Type 2-3 is just as harsh a judge of his or her own work and behavior. And as a result, the Type 2-3 personality may occasionally struggle with discouragement.

Type 1-3, "The Peacemaker"

The Type 1-3 personality will tend to be thoughtful and perceptive, but not particularly active. Of all the personality types, the Type 1-3 will tend to be the kindest, the gentlest, the most concerned for the feelings of others, and the least likely to be accidentally offended. If Type 2s provoke conflict, Type 1-3s studiously try to avoid conflict, and will instead go to great lengths to promote teamwork and good feelings amongst all the members of the group. A Type 1-3 is often a good debater, combining the extemporaneous verbal skills of a Type 1 with the reasoning skills of a Type 3.

On a design team, the Type 1-3 personality may perform his or her best service by acting as a team builder and peacemaker, and by helping to resolve disputes between parties. In addition, the Type 1-3 could also serve as the spokesperson for the group, although they would be quite willing to let someone else, like the Type 1-2, take that spotlight if they so desired. If a Type 1-3 were to serve as a team leader, he or she would tend to govern by consensus rather than by decree, but would likely have difficulty making the really hard decisions, especially if there is not much time for thinking it over.

Type 1-2-3, "The Troubleshooter"

The Type 1-2-3 personality, as the name implies, contains a little bit of each personality type. As a result, the Type 1-2-3 person is perhaps the best rounded of any of the other personality types. According to strict Peircian theory, the addition of the missing element of feeling to a Type 2-3 Inspector personality creates the Type 1-2-3 personality. But we could also think of this person as a more thoughtful Type 1-2 Leader personality, or as a more motivated Type 1-3 Peacemaker. As a result, the Type 1-2-3 personality has the ability to switch back and forth to serve in a variety of roles as the situation demands. Actually, every personality type does the same thing, but to a limited amount. Most people can serve in at least two of the seven roles with some degree of success, it is just that one role is likely to feel more comfortable. The Type 1-2-3, however, is specially adapted to being adaptable.

Thus on a design team, the Type 1-2-3 may end up serving in a variety of roles, floating from assignment to assignment as needed to keep the project on schedule and on target. A glance at Figure 2 above will reveal that the Type 1-2-3 occupies the same position on the smaller triangle as the Type 1-2 Leader personality does on the larger triangle. This means that relative to the other members in the small triangle, the Type 1-2-3 will *seem* like a Type 1-2 natural leader. Although the Type 1-2-3 will make decisions faster and with more intuition than its other Type 3 neighbors, the Type 1-2-3 is less hasty and more thoughtful than the regular Type 1-2 Leader. However, the Type 1-2-3 personality will not have the same need for attention that the Type 1-2 does, so would most likely gladly yield the reins of leadership if there is a capable Type 1-2 available.

In terms of assigning members to teams, we hypothesize that a minimum team should have one person assigned to each node of the Peircian triad. The first expansion has three members, so the minimum functional team consists of a Type 1, a Type 2 and a Type 3 individual. This will create a stable system. Sometimes, however, a system can be too stable to be responsive. For example, modern fighter aircraft are deliberately built to be unstable so that they can maneuver quickly. The same idea applies to design teams. A three-member team can work well, but the proposed theory suggests that it could be improved by adding a member at the first node of the next expansion. In this case, we should add to the three-member team a type 1-2 "Leader" personality to improve the responsiveness of the system. Thus our theory supports the empirical discovery of Hunkeler and Sharp⁴ that four-person teams are more efficient than three-person teams. The size of the design team can be expanded to any arbitrary size by filling all the nodes at any level of the Peircian expansion plus the first expansion from the next level. At the second level, there are six nodes, to which we add the Type 1-2-3 "Troubleshooter" personality from the third level of expansion to complete the ideal seven-member team.

Personality Survey

Having discussed the theory of personality to be used and the seven resulting personality types, we will now discuss the instrument designed to assess the personality type of an individual. The personality survey was constructed in two parts. The first part of the survey consisted of 28 questions designed to identify a person's characteristic personality type by assessing how that person would react under certain common scenarios. For example, one question reads, "When you play sports, what best describes your attitude?" Another question reads, "When faced with an unpleasant task, how do you tend to react?" Each question has four possible answers, of which three are meant to typify the three primary personality types, and one represents the response one of the four derived personality types. Thus, the three primary personality types are represented in all 28 questions, while the four derived personality types are only represented in 7 questions each. The first part of the survey is used mainly to identify which of the three main personality types a person favors. The second part of the survey is designed to help identify persons who are best described by one of the four derived personality types. The second section of the survey repeats the same 28 questions, but this time the four possible responses represent the four derived personality types. The survey was administered interactively by filling out a form on the World Wide Web¹¹. The raw survey results for each student were stored in a database for later retrieval and analysis.

Scoring Method

The raw results from the survey reported the personality type (Type 1, Type 2, etc.) of the response chosen by the user for each of the 28 questions in the two parts of the survey. One actual student's scores, identified only as "Student A" for privacy reasons, are shown in Table 1.0 below, as well as the results for the "null case." The null case represents what one would get, on average, if random answers were given. Notice that on average the null case would have 7 answers from the first part of the survey that would be divided among the 4 derived personality types, thus giving rise to the non-integer value of 1.75 shown below.

| | Survey Part 1 | | | | | | | Survey Part 2 | | | |
|-----------|---------------|--------|--------|----------|----------|----------|------------|---------------|----------|----------|------------|
| | Type 1 | Type 2 | Type 3 | Type 1-3 | Type 1-2 | Type 2-3 | Type 1-2-3 | Type 1-3 | Type 1-2 | Type 2-3 | Type 1-2-3 |
| Student A | 3 | 6 | 8 | 1 | 2 | 5 | 3 | 4 | 5 | 9 | 10 |
| Null Case | 7 | 7 | 7 | 1.75 | 1.75 | 1.75 | 1.75 | 7 | 7 | 7 | 7 |

Table 1.0 - Raw Survey Results

Next, the survey responses were tabulated according to their primary component parts. Derived personality type responses, such as Type 1-3 responses, were counted as *both* a Type 1 response and a Type 3 response. For example, for student A, the raw primary score for Type 1 was obtained by adding up all the responses with a Type 1 component from the two parts of the survey shown in Table 1.0 above. From the first part of the survey, we had responses with Type 1 components as follows: Type 1 (3), Type 1-3 (1), Type 1-2 (2), and Type 1-2-3 (3), for a subtotal of 9. On the second part of the survey, responses with Type 1 components were: Type 1-3 (4), Type 1-2 (5), and Type 1-2-3 (10), for a subtotal of 19, and a total raw primary Type 1 score, from both parts of the survey, of 28, as shown in Table 2.0 below. A similar process was used to obtain raw primary Type 2 and Type 3 scores. These scores were then compared to how much they deviated from the null case, as shown in Table 2.0 below.

| | Raw Primary Scores | | | Deviation from Null | | |
|-----------|--------------------|--------|--------|---------------------|--------|--------|
| | Type 1 | Type 2 | Type 3 | Type 1 | Type 2 | Type 3 |
| Student A | 28 | 40 | 40 | -5.25 | 6.75 | 6.75 |
| Null Case | 33.25 | 33.25 | 33.25 | 0 | 0 | 0 |

Table 2.0 - Reduced Survey Results

Notice that the deviation from the null can be either positive (+), or non-positive (-), and that the three personality types can take on eight different combinations of positive or non-positive deviation from the null. This was used to map the reduced results, shown in Table 2.0 above, to a distinct personality type as shown in Table 3.0 below.

| Deviation from Null Type 1 | Type 2 | Type 3 | Assigned Type |
|----------------------------|--------|--------|---------------|
| + | - | - | Type 1 |
| - | + | - | Type 2 |
| - | - | + | Type 3 |
| + | + | - | Type 1-2 |
| - | + | + | Type 2-3 |
| + | - | + | Type 1-3 |
| + | + | + | Type 1-2-3 |
| - | - | - | Type 0 |

Table 3.0 - Assignment of Personality Type

Notice that a new personality type, Type 0, has been introduced to account for the null case, and for another situation that will be described presently.

The personality type assigned by the manner shown above represents an absolute form of categorization relative to the null case. This absolute personality type would be useful for the initial assignment of members to design teams. However, once a group of people has been assigned to a team, a more relevant task would be to discover what each individual's personality type would be relative to the other members of the team. This can be accomplished simply by calculating the mean of the individual raw primary personality scores, as shown in Table 2.0 above, for all the team members. Then, the necessary deviations can be calculated from this mean score, rather than from the null case score. Once the deviations are calculated, a relative personality type can be assigned using Table 3.0. The hypothesis is that this relative personality type would be useful in predicting the roles that a person would be likely to assume on a design team, and in diagnosing breakdowns in team function.

Notice that since a team could be made up of any combination of personality types, it is quite possible for someone who has a low deviation from the null case on the absolute scale to have scores that are all negative relative to the mean of the team, and to be assigned a relative personality Type 0. A Type 0 personality will be similar to a Type 1-2-3, in that the scores for all three primary types will likely be relatively level. However, the Type 0 will be a relatively weak personality type since the rest of the team (on average) has more of each primary personality type than does the Type 0. As a result, it will be difficult for a Type 0 personality to find a meaningful place on a team, because this person will not be the "best" at anything. This assumes, of course, that the other team members have a similar set of skills that are relevant to the project. Theoretically this will be true for engineering students that have all been through the same course of study, but in practice it is often not true at all. Often one member of the team will have a specialized skill, such as the ability to perform TIG welding. If that skill is required for the design project, that person will have a meaningful place on the team regardless of personality type.

Team Functionality Survey

A team functionality survey was created, as shown in Appendix A, for the purpose of identifying the roles that each member fulfilled on the team, and for evaluating the ability of the team to function well together. After listing his or her name and the other members of the team, the respondent is asked to identify the individual(s) on the team who served in what roles on the team. Next, the respondent is asked to describe the method(s) (if any) used to choose a leader and assign roles to individuals. Also, the respondent is asked to rate the functionality of the team (on a scale of 1 - 10) and to decide if he or she would choose to work with this team again in the future. Finally, the respondent is asked to identify any pairs of people who experienced conflicts during the course of the team design project. The survey was worded in such a way that the student was never asked to criticize any member of the group.

Administration of Surveys

The personality survey and the team functionality surveys were administered to one senior design team and to ten freshman design teams during the final exam period of the class. In all cases the students had been allowed to select their own team at the beginning of the semester and to select their roles within the team without interference from the instructors. The only slight exception was the senior design team, because the class was so small that everyone had to be on the same team by default. The students were made aware that the results of the survey would not have any affect on their grade or that of their teammates, and every effort was made to insure the confidentiality of the responses.

IV. Results

The average grade issued by the instructor for the team design projects was 86%. Other results resulting from the administration of the two surveys are shown in Appendix B. The average functionality score (on a scale from 1 - 10) for each team was 7.15.

Ten of the eleven teams had at least one member who would prefer not to work on the same team again. On two teams, over half of the members said they would not like to work with the same team again. Significant conflict between certain members of the group was reported in 3 of the 11 teams (B, C, and J). On team B, a Type 2 member was identified as having conflicts with both of the other members of the group. On team C, a Type 1-3 individual was severely criticized for failing to attend meetings and shoulder a fair share of the workload. On team J, every member of the team was reported to have had conflicts with a certain Type 2-3 individual, but that individual reported that he had not experienced any conflicts with anyone at all.

Of the eleven teams, two (Teams C and E) had promising initial mixes of personality types relative to the null case, and of those two, only Team C had a relatively sound theoretical mix of personalities relative to each other, and that team had the highest functionality score (8.3). However, even the "best" team had some theoretical difficulties that made it less than optimal. For example, Team C only had three members rather than four, and rather than having one member from each of the primary types, this team had one member from each of the derived types. There were three other teams (D, F, and H) that had poor initial combinations of

personalities relative to the null case, but that by chance achieved relatively good distributions relative to the membership of the team. Two out of three of these teams (F and H) had below average functionality scores.

Individual students ended up serving in an appropriate role within the team (according to the theory) 10 out of 39 times. None of the teams had all their members serving in an appropriate role, and in 9 out of 11 teams half or more of the members were serving in an inappropriate role. Of the two teams where more than half of the members were serving in an appropriate role (Teams A and C), both scored above average on team functionality (as rated by the students) and the team with the highest proportion of members in an appropriate role (Team C) also had the highest functionality score (8.3).

V. Discussion of Results

With respect to the issue of conflicts, the data is explained precisely by the proposed theory. The theory suggests that it will be the Type 2 individuals who will tend to provoke conflict, as was seen in Team B, and that Type 1-3 individuals might tend to be less motivated, as was seen on Team C, and that Type 2-3 individuals can unintentionally exasperate their colleagues with their insistence that things should be just so, as was dramatically illustrated on Team J. In this case, the individual in question was a strong Type 2-3 "Inspector" personality and identified himself as the one "most concerned with making sure that the work produced by the group was in line with specifications and guidelines." His teammates perceived him as insufferable.

With respect to the assignment of personnel to teams, we have only one data point, but it is encouraging to note that the best functionality score was achieved by the only team that had a reasonably good mix of personalities relative to both the null case and relative to the team mean. From the limited data available, it appears that a team is not likely to succeed unless it initially has a good mix relative to the null case, even if the distribution relative to the mean is somewhat good.

The limited available data also support the proposed theory that the assignment of team members to appropriate roles within the team can also have a positive effect on performance. The two cases where more than half of the members were in appropriate roles scored above average, and the best score was achieved by the team having the highest percentage of members in the appropriate role.

VI. Summary and Conclusions

In summary, a new theory of personality has been proposed as a tool for assigning personnel to engineering design teams. This theory has been tested for one semester on eleven design teams. Although the data sample is too small to draw any firm conclusions, the results are certainly sufficiently encouraging to merit further consideration of the proposed method. From the limited data available, it would appear that the proposed theory is useful for explaining the sources of conflict within the sample set, and for explaining the success of the most successful design teams. Future work will include the use of the proposed theory to assign design teams, and to assign members to roles within those teams.

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Appendix A

Team Functionality Survey

Instructions: Please answer each question in the space provided below. In some of the questions below, you will be asked about what team members filled certain functional roles within your group. Notice that it is permissible to name a given team member more than once if that person filled more than one role. Likewise, it is also permissible to not name a team member at all if he or she did not fill any of the roles listed below.

1. Give your name: _____
2. List the individual members on your team by name.
3. Which member of your team would you say was the major source of creative ideas?
4. Which member of your team would you say was the person most likely to actually jump in and start working?
5. Which member of your team would you say did most of the "thinking" type work on the project?
6. Which member of your group would you say served as the group leader, either by election or by default?
7. Which member of your group would you say most often functioned as the peacemaker, or the one who kept the group working together as a team?
8. Which member of your group would you say was the most persuasive, either in internal discussions, or in external presentations, or both?
9. Which member of your group would you say was most concerned with making sure that the work produced by the group was in line with specifications and guidelines?
10. If you were assigned to do another design project, and if you could choose your own teammates, would you choose to work with this exact same team again (Yes or No)?
11. How would you rate the overall ability of your team to work together harmoniously to produce a good result? Rate your team on a scale from 1 to 10, with 1 being the least functional team, and 10 being the most functional team.
12. How did your group decide who would function in different roles? Circle the appropriate answer (a, b, c, or d).
 - a. The roles were assigned by the instructor, or another external entity.
 - b. We held an election of some kind.
 - c. We did not formally assign roles.
 - d. Other. Please explain.
13. It is natural for teams to sometimes experience internal conflict. Without assigning blame to anyone, name any pairs of team members who you observed experiencing conflict. Example, Joe and Dan; Bob and Susan; Dan and Ted.
14. If formal roles were assigned to anyone in your group (such as team leader, treasurer, head of manufacturing, head of fund raising, etc.), please list them below, along with the member of your group assigned to that role.
Example: Paul - team leader; Susan - treasurer; Bob - public relations.

Appendix B

| Team / Average Functionality Score (1 - 10) / Conflict? | Relative to Null | Relative to Team Mean | Role(s) Taken on Team | Serving in Appropriate Role? | Work With Same Team Again? |
|--|-------------------------|------------------------------|------------------------------|-------------------------------------|-----------------------------------|
| Team A | Type 3 | Type 1 | | N | Y |
| 7.2 | Type 3 | Type 2-3 | | N | Y |
| No | Type 2-3 | Type 2 | Types 2,1-2,1-3 | Y | N |
| | Type 3 | Type 0 | Types 2,3,2-3 | Y | N |
| | Type 1-3 | Type 1-3 | Type 1,1-3 | Y | Y |
| Team B | Type 2 | Type 2 | Type 1 | N | Y |
| 7.7 | Type 1-3 | Type 1-3 | Type 2 | N | N |
| Yes | Type 1-2-3 | Type 2 | Types 3,2-3 | N | N |
| Team C | Type 2 | Type 1-2 | | N | Y |
| 8.3 | Type 3 | Type 2-3 | Type 2,3,1-2,1-3 | Y | N |
| Yes | Type 1-3 | Type 1-3 | Type 1-3 | Y | Y |
| Team D | Type 1-3 | Type 1-3 | Type 3,1-2,2-3 | N | N |
| 7.8 | Type 2 | Type 2 | | N | Y |
| No | Type 2 | Type 1-2 | Type 1,1-3 | N | Y |
| | Type 3 | Type 3 | Type 2 | N | Y |
| Team E | Type 2-3 | Type 2-3 | | N | Y |
| 6.7 | Type 1-2 | Type 2 | | N | Y |
| No | Type 1-3 | Type 1-3 | Type 1,2,3,1-2 | Y | N |
| Team F | Type 3 | Type 1 | Type 3,1-2,1-3,2-3 | N | Y |
| 7 / No | Type 2-3 | Type 2-3 | | N | Y |
| Team G | Type 1-3 | Type 1 | Type 2 | N | Y |
| 6.3 | Type 3 | Type 3 | Type 3,1-2,2-3 | Y | N |
| No | Type 1-2 | Type 1-2 | Type 1-3 | N | N |
| Team H | Type 3 | Type 1-2 | Type 1,2,3,1-3 | Y | Y |
| 6.5 / No | Type 3 | Type 3 | Type 1-2-3,2-3 | N | N |
| Team I | Type 1-2-3 | Type 1-2 | | N | Y |
| 7 / No | Type 3 | Type 3 | Type 1-2,2-3 | N | N |
| | Type 1-2 | Type 2 | Type 1,2,3 | Y | Y |
| | Type 3 | Type 3 | | N | Y |
| Team J | Type 3 | Type 2-3 | Type 1,2,3,1-2-3,1-2,2-3 | Y | N |
| 6.9 / Yes | Type 3 | Type 1-3 | | N | Y |
| | Type 3 | Type 1 | | N | Y |
| | Type 3 | Type 2-3 | | N | Y |
| | Type 3 | Type 1-2 | | N | Y |
| | Type 3 | Type 1-2-3 | | N | N |
| | Type 2-3 | Type 2 | | N | N |
| Team K | Type 3 | Type 3 | Type 1-3 | N | N |
| 7.3 / No | Type 3 | Type 3 | Type 2,1-2,2-3 | N | Y |
| | Type 2 | Type 1-2 | Type 3,1-3 | N | Y |

