AC 2008-2381: GROUP SELECTION TECHNIQUES FOR A MECHANICAL ENGINEERING SENIOR DESIGN PROJECT COURSE

Gregory Watkins, California State University, Chico

Group Selection Techniques for a Mechanical Engineering Senior Design Project Course

Abstract

The mechanical engineering program at California State University Chico utilizes a two-semester capstone course in senior design project. It is required that students perform the project work in groups, as that is a measured outcome in the course. Assigning students to groups has long been problematic, with no satisfactory solution despite numerous attempted methodologies.

A new paradigm for the assignment of student groups was implemented in the fall of 2007. Typical design team roles were identified based on Belbin's research into the deliberation process. Students were asked to identify their preferred roles on a design team, as well as their preferred projects to work on. Projects teams were then formed by the faculty using the information supplied by the students.

This paper details the process of team selection and the measures taken to assess its effectiveness. It summarizes the overall success of the paradigm, and provides suggestions for future use.

Overview of Senior Design Project

As with many engineering programs, the mechanical engineering curriculum at California State University Chico utilizes a two-semester capstone course in senior design project. The intent is for students to utilize competencies developed in the first three years of the curriculum in the solution of a real-world design problem. The fall semester is predominantly spent in design activities, while the spring encompasses prototype building and testing. Projects may come from local industry, may be competition based, or may come from other sources.

During the fall semester, weekly lectures are given that cover many aspects of the design process. Selected topics include specifications definition, conceptual design, decision making, project planning, cost estimating, budgets, documentation and formal reports. Students are required to give three oral presentations during the semester. The presentation topics are project proposal, midterm review, and final design. The semester concludes with submission of a comprehensive design report.

The spring semester includes less time in the classroom and more time spent building and testing the designs. Students are required to develop a comprehensive test plan to prove the specifications developed in the fall semester. They then fabricate and test the design, and in most cases, proceed directly to redesign activities. The semester concludes with a final oral presentation and submission of a comprehensive written report.

Student Groups

It is a requirement that the design projects be accomplished by student groups, as the ability to work in groups is one of the measured outcomes of the course. A major issue involved in this is the assignment of students to groups and projects. In the past, various methods have been utilized with varied levels of success.

A common and straightforward method employed previously was to simply allow students to form their own groups and suggest their own projects. This method generally resulted in both successes and failures. The self-grouping paradigm almost always yielded a few very strong groups that worked well together and produced excellent designs. But it often also resulted in weak teams that struggled to successfully complete the project, and the course. It also had the disadvantage of allowing students to "buddy up" and work only with their friends, which hardly represents what can be expected once the students begin working in industry.

In another common method, faculty assigned students to groups based on their rankings of choices from a predefined list of projects. While this generally resulted in students working on projects they were interested in, it did not necessarily prevent buddying up, and was usually insufficient by itself to assign all students to projects. A common occurrence was for a majority of students to all want the same projects, while other projects garnered no interest at all. This forced the faculty to make sometimes unpopular decisions in getting all the projects assigned.

Team Roles in the Design Process

In order to develop an improved method of student team formation, various best practices were studied. This is clearly a thorny issue that has been widely discussed in the literature in both educational and industrial settings. Many methods are based in some way on assessing the student's personality traits such as Myers Briggs indicators[1] or The Big Five personality factors[2]. Papers specifically related to student team formation by Wesner[3], Wilde[4], and Adams[5] report on a number of differing strategies that may be instructive for the interested reader.

A source not widely reported on is research into team roles by R Meredith Belbin. His 1981 book, *Management Teams – Why they Succeed or Fail*[1], and a follow-up work, 1998's *Team Roles at Work*[2], studied the interaction of team members during the deliberation process. He identified eight predominant roles that members of successful teams occupy. They are:

1. Plant — The Innovator. Unorthodox, knowledgeable and imaginative, turning out loads of radical ideas. The creative engine-room that needs careful handling to be effective. Individualistic, disregarding practical details or protocol – can become an unguided missile.

2. Resource Investigator — The extrovert, enthusiastic communicator, with good connections outside the team. Enjoys exploring new ideas, responds well to challenges, and creates this attitude amongst others. Noisy and energetic, quickly loses interest, and can be lazy unless under pressure.

3.	Chairman	Calm, self-confident and decisive when necessary. The social leader of the group, ensuring individuals contribute fully, and guiding the team to success. Unlikely to bring great intellect or creativity.
4.	Shaper	Energetic, highly-strung, with a drive to get things done. They challenge inertia, ineffectiveness and complacency in the team, but can be abrasive, impatient and easily provoked. Good leaders of start-up or rapid-response teams.
5.	Monitor Evaluator	Unemotional, hardheaded and prudent. Good at assessing proposals, monitoring progress and preventing mistakes. Dispassionate, clever and discrete. Unlikely to motivate others, takes time to consider, may appear cold and uncommitted. Rarely wrong.
6.	Team Worker	Socially-oriented and sensitive to others. Provides an informal network of communication and support that spreads beyond the formal activities of the team. Often the unofficial or deputy leader, preventing feuding and fragmentation. Concern for team spirit may divert from getting the job done.
7.	Company Worker	The Organizer who turns plans into tasks. Conservative, hard-working, full of common sense, conscientious and methodical. Orthodox thinks who keeps the team focused on the tasks in hand. Lacks flexibility, and unresponsive to new ideas.
8.	Completer Finisher	Makes sure the team delivers. An orderly, anxious perfectionist who worries about everything. Maintains a permanent sense of urgency that can sometimes help and sometimes hinder the team. Good at follow-up and meeting deadlines.

The work suggests that successful teams have members occupying each of the eight roles. It goes on to suggest that selecting team members based on their ability to perform in a certain role is just as important as considering their technical skills or experience. Based on this work, it was decided that project teams would be formed utilizing the student's self-assessment of their preferred team role. The idea being that students working in roles they were best equipped to fill would result in successful project teams.

Utilizing Roles in Student Team Selection

Though not the result of formal research, past experience has shown that the optimum number of students on a senior design project team is about four. With many more than that, it is difficult for all students to remain engaged, and is especially difficult to ensure that each student gains sufficient knowledge and experience to meet the objectives of the course. Smaller teams can be problematic as well, as they can have trouble tackling projects of sufficient complexity to provide a viable design experience.

This presents an immediate problem for implementing Belbin's eight roles of a well functioning team. In order to adapt the eight-role model to four person teams, the eight categories had to be condensed into four with the eventual goal of establishing teams with one member in each category. The roles were studied for overlap and potential common traits, and were finally condensed into the following four team roles:

1. Planner / Organizer — Mature, confident, trusting, good at clarifying goals and promoting decision making. Not necessarily creative or clever.

2. Creator / Evaluator — Better with ideas rather than facts. Good at seeing the big picture, judging outcomes accurately, and is imaginative and creative.

3. Doer / Worker — Turns ideas into practical action. Disciplined, reliable, and efficient. Concerned about avoiding friction within the team.

4. Pusher / Finisher — Conscientious, detail oriented, delivers results on time. Inclined to worry about progress. Give me facts rather than ideas.

Implementing the New Paradigm

In the beginning of the semester, students were asked to assess themselves with regard to the four team roles, and to rank from first to last the role they were best equipped to occupy on the team. They were also asked to rank their top five project choices based on a predefined list of projects. As should be expected, some projects were much more popular than others, and this ranking alone would have been insufficient to assign students to all of the projects. While project choice was a primary selector, the students' self assessment of their preferred role was used as a secondary selector, with the goal of developing teams that would, it is hoped, work together effectively and cohesively.

This year's course enrolled 49 students, 48 of which returned the survey instrument. Results of the team role preference questionnaire are summarized in the following chart. Figure 1 shows a breakdown of the number of students that selected each of the four roles as their first, second, third, and fourth choices. While Creator/Evaluator was listed as the first choice by the highest number of students, and Pusher/Finisher was the least chosen category, there was still sufficient diversity in the data to assign students in each role.

The 49 students were assigned to eleven project teams of four students each, plus a twelfth team with five. In all cases but one, teams were formed with students occupying no lower than their second choice of team role. It should be noted that the results of the self-assessments were not shared with the class at this time. The primary reason was to let the students naturally fall into roles, without prescribing roles based on stated preferences. In hindsight, this was a good decision.
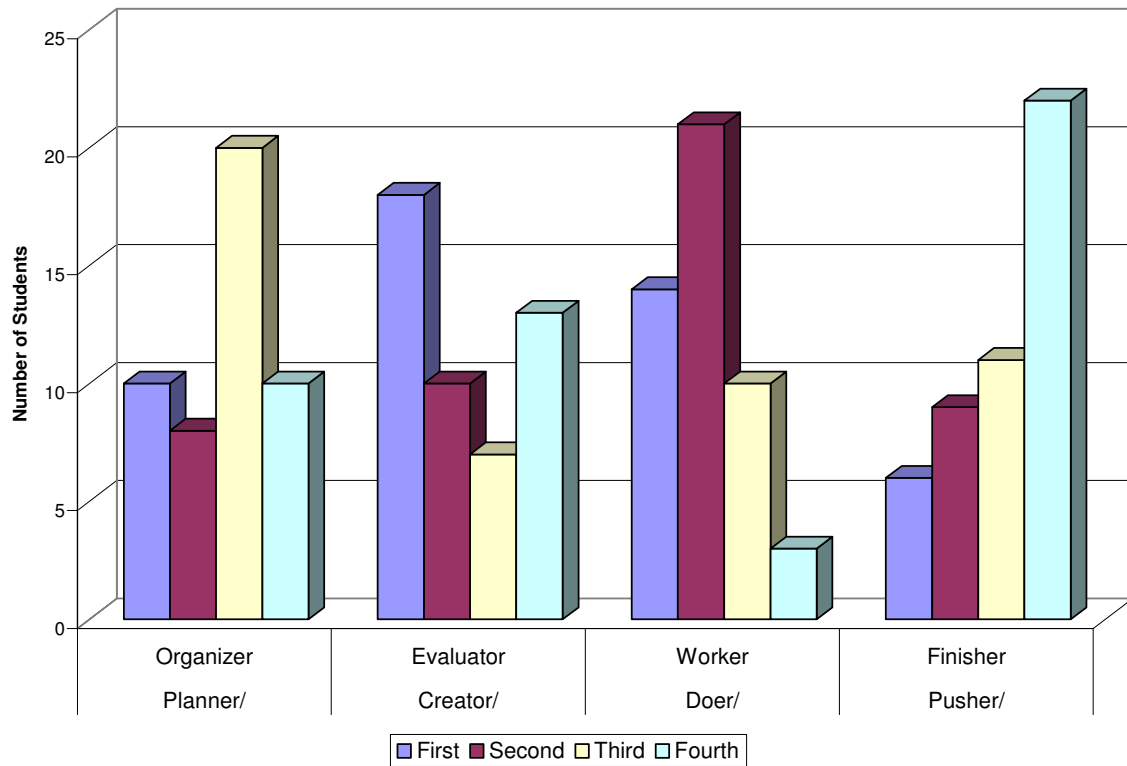
Figure 1 – Team Role Preference Survey Results

Assessment of the New Paradigm

An end-of-semester survey was developed as the primary tool to assess the effectiveness of this new procedure for student assignment to groups. The survey was administered at the end of the fall semester when design activities were complete, but build and test activities had yet to begin. Even though much work remained for the students when the survey was administered, they had already spent a full four months working together on their formal designs, presentations, and formal documentation.

It should be noted that not until the time of the survey were the students provided a matrix indicating the team role preference rankings for all students in the class. So unless they discussed their role preferences among themselves, they did not know how the other group members responded to the initial team role survey. The seven-question survey instrument is included in appendix A. Survey results are summarized in Figure 7 below. Q1 through Q7 correspond to the seven questions in the survey, which are repeated in Table 1 below the figure.
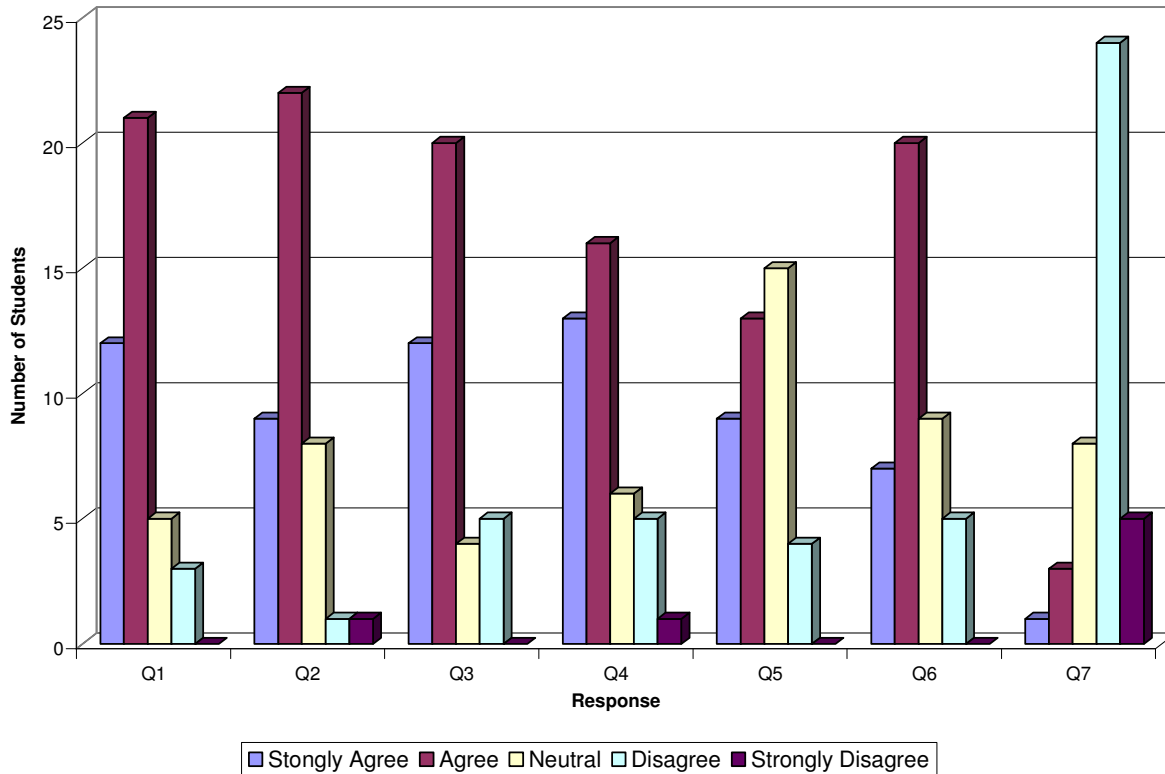
Figure 7 – End of Semester Survey Results

Table 1 – Survey Questions

Q1   I generally assumed the role that was my first or second choice in the rankings.

Q2   Most of my teammates generally assumed their first or second choice roles.

Q3   If I had to do it over again, my role preference rankings would be mostly the same.

Q4   With a few exceptions, my project group generally functioned well as a team

Q5   In our case, this process helped create a project group with members of diverse skills that assumed different and effective roles.

Q6   I would recommend a similar approach be used for team formation in future editions of the Senior Project course.

Q7   Role preference should be used as the first criteria when assembling project teams, rather than project choice.

In addition to citing agreement or disagreement with the statements, students were encouraged to include written comments where appropriate to help clarify their responses. Selected comments are included below, grouped by general theme:

Generally Complimentary:

- *It worked great*
- *I was actually very surprised at how well we functioned*
- *They were strong in the areas I wasn't*
- *This approach worked <u>really</u> well for us, but maybe not so well for other groups*
- *In our case, the process worked perfectly*
- *The team formed by this method worked out great*
- *Everyone seemed to fall into the role they chose*
- *It was evident by the end of the semester that we all had assumed roles*
- *There's no magic bullet for a team full of slackers, but this method worked very well in our case*
- *Our functionality roles were spot on*
- *Looking back on the semester, I believe I acted most like the role I selected*

Constructive Criticism:

- *I think that groups should be chosen more or less at random*
- *More student input; present these numbers and force a 1,2,3,4 team with students deciding the teams*
- *We all had varied skills, but I think there is more to it than four criteria; effectiveness suffered*
- *I suggest that before the groups get formed; make sure everybody gets along prior to the beginning of the project*
- *It is a good approach, but project choice is more important. Students can adapt to different roles.*

Of General Interest:

- *I realized a few things about myself that I didn't know beforehand*
- *Team disfunctionality is a learning experience*

Discussion of Results

Survey data and written comments suggest that this new paradigm was largely successful in assigning students to senior project groups. It is not a perfect system, of course, though it is unrealistic to expect any method to produce 100% successful groups. Further examination of the data leads to some interesting and sometime conflicting conclusions, as discussed below.

The percentage of students stating either strong or general agreement to the first four questions is 81%, 76%, 78%, & 71% respectively. Taken together, this would seem to indicate that the team

role concept was useful and resulted in diverse teams with differing skill sets. However the same percentage for question 5 drops to 54%, indicating some skepticism that the process produced teams with members occupying different and effective roles. Perhaps more telling is that 66% would recommend the process for future editions of the course.

The results of question 7 paint a clear picture of student preference, which in hindsight, is not surprising. Fully 79% disagree with using this method as a first criterion rather than project choice for assigning students to project teams. It is clear from the data and comments that students strongly desire to have some input into the project they are assigned.

Two Exceptions

As mentioned earlier, students were not told of their roles when projects were assigned. There were, however, two exceptions. Due to unexpected circumstances, a single group ended up without a project. When notification was sent to the group, the planner/organizer was identified, with the suggestion that he/she take the lead in establishing a new project. A comment from his/her survey is illuminating:

- *You told my group I was the planner/organizer. I was then locked into this role and constantly looked at to fulfill it. If kept anonymous, I could have used my skills in this area without being forced into one role.*

The other exception also produced an interesting result. As mentioned earlier, project choice was used as a first selection criterion, with team role preference being secondary. With one exception, all teams were formed with students occupying no lower than their second choice of team role. The exception resulted from a small group of students all having a first preference for a particular project, with virtually no other students showing any interest in it at all. As a result, this single team was formed with nearly identical members from a team role point of view. Four of the five members selected creator/evaluator as their first choice, while all five listed doer/worker as their second. This group generally struggled with their project, did not work well together, and experienced numerous conflicts among its members. Comments from their surveys are interesting, though it should be noted that they were informed of their "mismatch" early in the term (a mistake in hindsight):

- *All members had similar skills*
- *Good concept – not so much with our group*
- *Although we were the exception, I liked the idea of picking what roles we thought we were.*

While this is but a single sample, it does provide further evidence of the effectiveness of this approach, and suggests that it should be followed for all project teams without exception.

Recommendations

During it's first use, this new paradigm for assigning students to senior project groups provided generally good results, and will certainly be used again in future editions of the course. Based on

this initial experience, the following suggestions are provided for the benefit of others that may choose to pursue a similar approach in their courses.

- After the groups are formed, do not share the students' choices of team role with the class. Doing so tends to force the students into roles based on a single inexperienced judgment. It is much more effective to let the students assume their own roles within the group, regardless of their initial self assessment.

- Do use project choice as a first criterion when assigning students to groups, and then use this method as a second criterion. Project choice is normally insufficient, as many students will all want the same projects, and a second means must be employed. Using this method, aside from forming effective groups, also provides a fair and impartial method, resulting in little to no student resentment for not being assigned to their preferred project.

- Do not let project choice force you into assembling a team with too many similar role preferences. This single set of data shows that the process generally produces good results when it is applied and, at least in one case, produced unfavorable results when it was ignored.

Bibliography

1. Briggs, M. I., *Manual: The Myers-Briggs Type Indicator*, Palo Alto, CA, Consulting Psychologists Press, 1962.
2. Kichuk, S. L. & Wiesner, W. H., *The Big Five Personality Factors and Team Performance: Implications for Selecting Successful Product Design Teams,* Journal of Engineering and Technology Management, 14 (1997)
3. Wesner, J. W. et al., *Student Team Formation and Assignment in a Multi-disciplinary Engineering Design Projects Course: a Pair of Suggested Best Practices,* International Journal of Engineering Education, Volume 23, Number 3, May 2007
4. Wilde, D. J., *Using Student Preferences to Guide Design Team Composition*, Proceedings of ASME Design Engineering Technical Conference, September 1997
5. Adams S., & Okudan, G. E., *A Comprehensive Model for Student Design Team Formation and Performance in the Engineering Classroom.* Proceedings of the International Conference on Engineering Education, July 2003
6. Belbin, R. M., Management Teams: Why the Succeed or Fail, London, Heinemann, 1981
7. Belbin , R. M., Team Roles at Work, Oxford, Butterworth-Heinemann, 1993

Appendix A – Team Functionality Survey

1. I generally assumed the role that was my first or second choice in the rankings.

    Strongly Agree   *Agree*   *Neutral*   *Disagree*   *Strongly Disagree*

    Comments:

2. Most of my teammates generally assumed their first or second choice roles.

    Strongly Agree   *Agree*   *Neutral*   *Disagree*   *Strongly Disagree*

    Comments:

3. If I had to do it over again, my role preference rankings would be mostly the same.

    Strongly Agree   *Agree*   *Neutral*   *Disagree*   *Strongly Disagree*

    Comments:

4. With a few exceptions, my project group generally functioned well as a team.

    Strongly Agree   *Agree*   *Neutral*   *Disagree*   *Strongly Disagree*

    Comments:

5. In our case, this process helped create a project group with members of diverse skills that assumed different and effective roles.

    Strongly Agree   *Agree*   *Neutral*   *Disagree*   *Strongly Disagree*

    Comments:

6. I would recommend a similar approach be used for team formation in future editions of the Senior Project course.

    Strongly Agree   *Agree*   *Neutral*   *Disagree*   *Strongly Disagree*

    Comments:

7. Role preference should be used as the first criteria when assembling project teams, rather than project choice.

    Strongly Agree   *Agree*   *Neutral*   *Disagree*   *Strongly Disagree*

    Comments: