Team Grouping Strategies in Freshman Engineering Design Courses

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Abstract - **Team cohesiveness is crucial to the success and completion of a project or goal. Team integration has been tested for many years, and several methods have been developed to aid in determining the best team formation. The work presented here, assesses freshman engineering students, and the success of group based projects. To assess team success, students from freshman engineering design classes were grouped into teams using different strategies. One class used an academic/grade based method to determine groups, placing similarly ranked students in the same group. A second class grouped students by academic rank, but included one high, middle and low ranking student in each group. A third class used random draw as its grouping method. These results are compared to those obtained at a different institution where entering academic composites were used to form groups of students with similar high school performance. Through these freshman design courses, students reflected several times using peer review to assess their teammates on criteria of: ability to gather information; fulfilling team roles; ability to listen; and conflict resolution. These metrics created a comparison that is used to determine an optimal method for future group selection in design courses.**

Index Terms – Course, Design, Grouping.

INTRODUCTION

The first years of college are very important to a student's learning and understanding within any field of study. The foundation of fundamental practices and thought processes are first being introduced to and developed within the student. This time is crucial to engineering students, who need to understand how to apply mathematics and physics to applications. Along with applying engineering principles, it is important to introduce students to working in teams; in fact this is a requirement from ABET (Outcome D), the accrediting board for engineering curriculum[5]. Introducing students to both individual activities as well as group activities has resulted in higher performance and higher retention rates of students[1, 2]. Further, a mix of individualism and group pedagogies ensures a well rounded experience[3]. Individualism is important because it allows for expression, innovation and idea creation; but working in groups allows those ideas to be expressed and verified by their peers.

With the advancement of technology, more specialized fields and cross-disciplinary research, multidisciplinary groups are necessary to complete and integrate projects. Therefore it is important to instill the capabilities and goals of good teamwork skills into engineering students at this fundamental stage.

One vehicle to introduce teamwork skills is through design courses. According to Scott et al., it is important for students to receive a mix of problem-based learning and project–based learning, and the design course enables the students to receive the latter[4]. Another student outcome expected from ABET is that students have the capability to function on multidisciplinary teams [5] , and employers are expecting this ability.

Project based courses provide faculty an opportunity to introduce students to the design process as well as multidisciplinary teams as freshman students have not decided a major. These courses take the student through a complete project from ideation/conception to operation. One design process has been outlined by MIT; this is the Conceive, Design, Implement, Operate (CDIO) process [6, 7]. Students are given a problem statement with a set of goals to meet by the end of the semester. They proceed through each stage: 1) conceiving methods for solving the posed problem, 2) designing different solutions and 3) implementing their best solution until the groups finally have to 4) test and/or operate the final solution. At the end of each stage students are asked to present and write reports as groups discussing their results.

This process provides a formal forum for the exchange of ideas. It allows groups to interact with each other to make sure the transfer of ideas is occurring throughout all stages of design. Integrating composition and oral presentation skills into engineering courses is effective in improving performance of students[1]. Further, a third ABET outcome is for students to communicate effectively [5].

Several tools have been developed to aid students in using their time effectively and to meet their outcomes. One of these tools, meeting agendas, are used to help divide responsibility and focus on project tasks. Establishment of responsibilities can lead to a cohesive and effective team. In addition peer evaluations are used for students to assess each other. From the instructor's perspective, these tools are an aid to assess team performance.

This information is used to understand the effect of different grouping strategies: random selection, distributed

TABLE I
LIKERT SCALE

Scale	Definition
1	Unsatisfactory – Peers did not contribute to meet desired goals
2	Developing – Peers met some but not all desired goals
3	Satisfactory – Peers met all desired goals
4	Exemplary – Peers went above and beyond expectations

academic rank, and similar academic ranks, in an introductory level design course. The faculty use final grade, grade point average (GPA) and academic composite to evaluate the grouping strategies.

METHODOLOGIES

Peer evaluation and peer to peer feedback are one of the best methods of understanding group dynamic. When students are informed that the peer evaluations are private and are used by the faculty to help improve their group interactions, it allows students to honestly rank their peers on their performance. While taking peer evaluations and combining this information with personal notes during observation of group dynamic and team performance, this data can aid in determining the best process for deciding groups.

To discuss this information further, a set of definitions will be set to not confuse discussion points.

Definitions:

- Class
  A single course taught to a single classroom of students.
- Group
  The teams created within a class
  In this study, 5 classes using 4 selection methods are discussed. Even though some classes were taught at different institutes, they all follow a process similar to the CDIO design process. The first 3 classes use a GPA based or random method to determine groups within a class, while the remaining two used an academic composite (defined below). These classes are as follows:
  - Similar Academic Rank
    Using Cumulative GPA of student prior to semester to setup students into high GPA teams, middle GPA teams, low GPA teams.
  - Random Academic Rank
    Randomization occurred through pulling numbers from a hat.
  - Distributed Academic Rank
    The distribution of GPA used to select groups was a combination of high GPA, middle GPA, and low GPA all combined into a single group.
  - Academic Composite Rank
    An introductory freshman engineering class taught at a different university. At this particular university, freshman engineering is a mandatory course that all students (regardless of major) must take. Data come from two separate sections of the course consisting of 30 students each. Upon entry into this university, students were given an "academic composite" that was a weighted measure of their high school academic performance/rigor and standardized test scores (SAT and/or ACT.) The academic composite is similar to that of a GPA but runs on a scale from 0-4000. To compare with GPA based classes, the academic composite has been scaled to a range from 0.0 – 4.0.

The similar academic rank, random academic rank and distributed academic rank classes use peer evaluation forms at the end of each phase of the CDIO process. For the purposes of this document, peer evaluations are only assessed at the end of implement and operate phases where the operate phase coincides with the students final grade. The reasoning for this is that these groups have never been formed before within the classes. Knowing that students need time to work together, develop rapport, and know their functional roles means that the peer evaluations may not be a true representation of the team and individual until they have had time to work cohesively.

The academic composite rank classes used peer evaluation forms only at the end of the semester. These peer evaluation forms were used to make actual changes to student group grades. In other words, points could be taken from a non-contributing team member and given to team members who contributed more than their share.

Peer evaluations need to be productive towards the advancement of team dynamic. Using questions designed in previous engineering design courses at the University of Southern Indiana, students had to assess their teammates on the following criteria:

- Researched and gathered information
- Fulfilled team roles when assigned
- Shared the work of the team
- Demonstrated good listening skill
- Helped resolve conflicts

Using these criteria as a method for assessment, individuals ranked their peers on a Likert scale (Table I). Students also had the ability to add comments. These evaluations were used to aid teachers in assessment of the group dynamic and to aid the students to improve teamwork skills.

RESULTS AND DISCUSSION

Similar Academic Rank Results

The similar academic rank cohort consisted of 5 groups. Within the class structure, 1 group had to make a change in the conceive stage due to early group dynamics issues and students dropping the class. However, after this change, there were no serious group dynamics issues. In terms of class assessment the high GPA group (top 3 students) were the most successful. In the second highest GPA group, 1 student took the reigns and controlled the group. Finally the middle GPA group worked the best as a group.

TABLE II
SAMPLE PEER EVALUATION RESULTS SINGLE GROUP

Implementation Phase					Operate Phase				
S	1	2	3	4	S	1	2	3	4
A	3.25	4.00	3.50	4.00	A	2.67	4.00	3.33	4.00
B	3.25	4.00	3.50	4.00	B	3.33	3.67	3.00	3.33
C	3.25	4.00	3.50	4.00	C	3.00	3.00	3.00	3.33
D	2.75	3.75	4.00	4.00	D	3.00	3.33	3.33	3.00
E	3.50	2.75	3.50	3.00	E	3.33	4.00	3.33	4.00
Notes:		S: Student							
		A - E: Criteria for Peer Evaluation							

Results (Figure 1) are consistent with those that one might expect: a positive slope indicating high GPA students received high grades in the course, and lower GPA students received lower grades in the course. These data also have one of the highest correlation ($R^2 = 0.368$) among this data set.

Random Selection Results

The random selection cohort only had two groups out of the six that had any formal issues. From the two groups that had issues, one group improved and was able to increase their teamwork capabilities, while the other group was not able to maintain a strong group presence and finished with lowest grade in the class.

To compare the other classes with the random academic rank, GPAs of the groups are combined to make overall assessment. GPAs in the class are broken down into 4 groups, high, middle high, middle low, and low. Five of the six groups contained at least 1 high GPA student. General observation was that all groups with a high GPA student were able to work in groups cohesively. One group, that did not have any high GPA students, had trouble working together and finishing their tasks. When looking at the randomization and how the groups were laid out, the group with the highest total GPAs finished the class with an above average input. They performed the necessary tasks to complete the course, but did not push the boundaries of the course while working together. The best performing group though was a group that had a mix of high GPA, middle high GPA, and middle low GPA. Their group excelled and completed the CDIO process strongly. To the extent that their video has been posted on YouTube, where there glider was asked to travel 75 feet and one flight managed approximately 300 feet.

The group that had the lowest performance had no high GPA members. The resulting grades are representative from their evaluations, (example evaluation layout in Table II). When the peer evaluations are assessed from group 5 in the random academic rank cohort it was observed that the group was not able to meld together as a unit. However, since the students are not forced to fill out peer evaluations not all of the group members filled out the peer evaluations. This may follow through with their capability to complete the class. The top-performing group at the end of the semester had a mix of GPAs.

When interpreting how the GPA reflected the overall grade of the students, the positive slope (Figure 2) is retained as observed in the similar rank group (Figure 1). What changes between these two groups, similar and random academic rank, and is evident in all groups, is that the random academic rank group had the lowest R-Squared value ($R^2 = 0.2112$). Since the R-Squared illustrates how well the data fits a linear line, the R-Squared value would be lower when groups of mixed GPA are combined. With the interaction of individuals of different GPAs interacting on a team, the teamwork thrived in these groups, and therefore pushed the grades higher for these students and therefore spreading the data when adhering a linear curve fit.

Distributed Academic Rank Results

The distributed academic rank cohort was broken down into 4 teams of 6 students each. Results from grouping students with distributed academic ranks indicate that the highest academically ranked (GPA = 3.138) group performed the best. This was also observed by the faculty during the class. The top 3 students were always working together to have the project succeed. The remaining students seemed content doing minimal work.

However, in the three lower-rank groups (GPA = 2.976, 2.911 and 2.816), work was distributed among the academically strong and weak students. The top tier students were still pushing the group towards success; everybody was contributing (Figure 3).

These data (Figures 3 and 2 respectively) indicate planned grouping by distributed academic rank ($R^2 = 0.231$) proves to be just as good as random selection ($R^2 = 0.21$). However, this method of grouping does force students to interact with students of different performance capabilities. The skills developed when working in this format should prove beneficial in the long run, but does risk the loss of students to other majors.

Bigger teams (5 – 6 students) certainly made it easier to "hide" their effort" – this was the motivation to designate smaller teams. Teams of 3 allowed for flexibility for the faculty to combine team working on similar projects if one or two students dropped out.

Academic Composite Rank Results

The results from the academic composite study proved interesting. For both sections of the course observed, the highest performing team turned out to be the team composed of the students with the highest academic composites. However, it was not always the case that the team scores equated to academic composite. In one section, the team that was the second highest in terms of academic composite turned out to be the worst in terms of team performance. In this particular section, there was no discernable correlation between team performance and academic composite ($R^2 = 0.154$, see Figure 5.) Within this class two students were removed. The first student was removed because of a missing academic composite, while the second was removed as an outlier. The team corresponding to this outlier was returned to its pre peer evaluation final grade. In the second section, although the

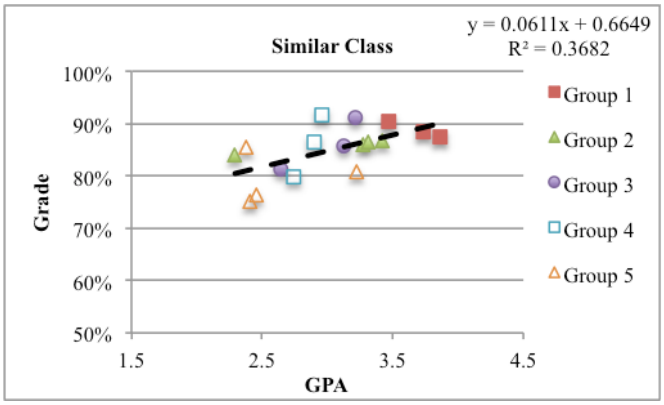

FIGURE 1
SIMILAR ACADEMIC RANK REPRESENTATION OF ENTERING GPA VS. FINAL GRADE.

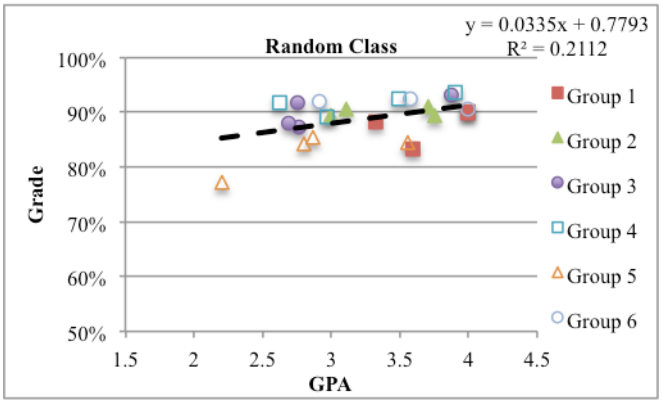

FIGURE 2
RANDOM ACADEMIC RANK REPRESENTATION OF ENTERING GPA VS. FINAL GRADE.

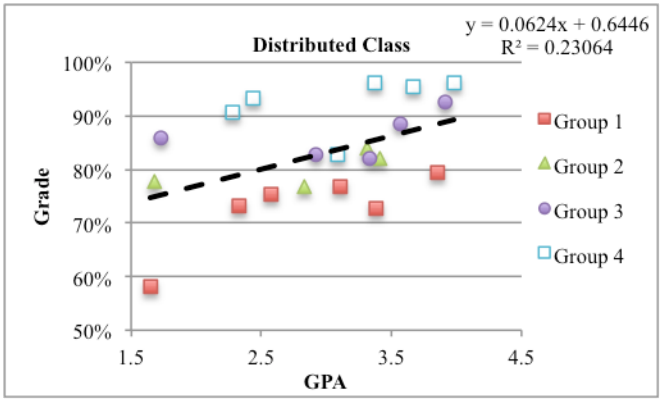

FIGURE 3
DISTRIBUTED REPRESENTATION OF ENTERING GPA VS. FINAL GRADE.

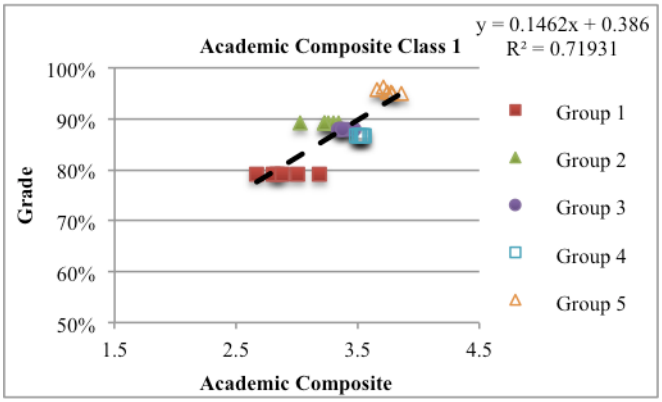

FIGURE 4
ACADEMIC COMPOSITE CLASS 1 RANK REPRESENTION OF ENTERING ACADEMIC COMPOSITION VS. FINAL GRADE.

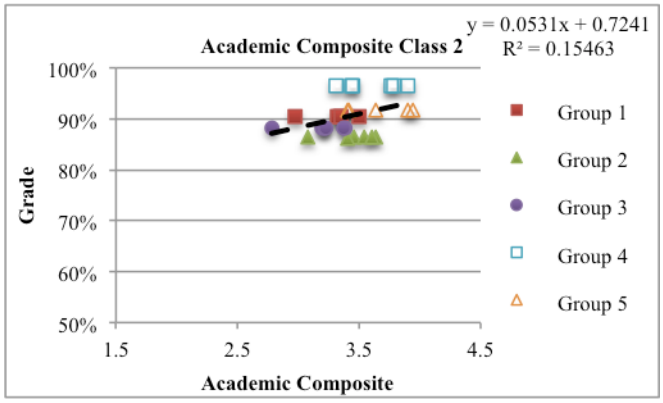

FIGURE 5
ACADEMIC COMPOSITE CLASS 2 RANK REPRESENTION OF ENTERING ACADEMIC COMPOSITION VS. FINAL GRADE

groups did not perform exactly in the order of their academic composites, there was a strong positive correlation between academic composite and group performance ($R^2 = 0.72$, see Figure 4.) Regarding the peer evaluations, only one team in each section elected to redistribute points to higher or lower performing team members.

Overall Observations

From all classes and group determination, it is important to recognize the relationship of the students overall grade

to the individuals GPA within in a select grouping strategy. It has been observed that in both the distributed academic rank and random academic rank classes, that an intermingling of multiple GPA students improves the performance of the students. Bringing students that would generally expected to perform at a sub-par level, can actually over perform and excel. This again can be seen in Figures 2 and 3 where the R-Squared values are lower than that of the similar groups (Figures 1 and 4). This could further lead to a direct correlation between group determination and team cohesiveness, but more data is needed to support this claim.

Within our similar ranking classes (Figure 1 and 4), while academic composite 2 (Figure 5) is being disregarded as an anomaly due to the bottom falling out, we see that our students perform as expected. The students with the higher GPA retained a higher grade at the end of the semester, while those with a lower GPA or academic rank ended with a lower final grade. This would also account for the higher R-Squared value that we see as the students are following that positive slope with relation to entering GPA and final GPA. It is interesting to see that the R-Squared would be as high as 0.72 in the academic composite class as that would suggest a tight fit to the data. Is it to take into consideration that again this is a mix of undecided students that are not allowed to select a major. Therefore this is truly a multidisciplinary team in action.

From analyzing the data that we have available, it is important to note that a smaller R-Squared may indicate a better team dynamic: that the members across multiple GPA groups are working together and driving each other to a similar grade, be that higher or lower than expected. The results would always resemble a lower fit of data to a linear line. Therefore using method such as a distributed ranking would act like a random drawn class and improve the performance of our students. More is necessary to solidify these results, but the initial observations can be made from the data sets presented in this work.

With continued work in understanding how our freshman design courses influence teamwork capabilities, it would be beneficial to enact other processes of group determination. Processes described in Felder et al., discuss the benefits of personality tests and their effects on improving team performance [8]. There may be a corollary effect, taking place when students of different GPAs are analyzed on their personalities, and this may be a driving factor on why we see beneficial results from the distributed and random ranking classes. Initiating personality tests such as the Myers-Briggs test and others may help shed light on improving team performance in design courses.

CONCLUSION

In the work presented, the authors introduce and give inferences and observations to different methods of group determination in freshman design courses. The data described does suggest that having groups with distributed GPA or randomized GPA can improve overall team performance. As discussed in the introduction, it is important for students to perform well in team based activities as it improves retention rates. Further data and analysis are necessary to confirm this notion, and integrating this information with personality information may shed more light on how the multiple GPAs really affect and improve team performance.

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