Work in Progress: Improving Team Performance in First-Year Engineering Students

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Introduction

Seat and Lord (1997) [1] discussed two types of student cognitive style theories. These are field independence and field dependence. Seat and Lord (1997) argues that these theories describe how technical students, or engineering students, learn new information. These theories involve students being classified as either independent or dependent learners, with engineering students falling into the category of independent learners. Independent learners are more impersonal, and prefer to work alone in their problem solving. This can lead to independent learners having poor interpersonal skills. They prefer their own conclusions in problem solving, than trusting the conclusions of others or the group. In contrast, dependent learners are more social and prefer to work in groups to problem solve [2].

A unique feature of EGR 100, an introductory engineering design course, is how teams are formed. Students are asked to pick a safe partner, someone they want to work with, and then each pair fills out a questionnaire to match them with another pair, forming a team of four. The questions the students answer involve their experience with writing and programming, as well as their university schedule and location. Based on the responses from these questions, each pair of students are matched with another pair of students with complementary skills. Another unique characteristic of this course involves students having the ability to change teams after the first design project. Students may desire to change teams if they feel that the rest of their team is underperforming, or if they feel that the other students on their team are overly demanding. These practices are informed by the above studies to encourage students to develop more dependent learning styles.

A self-reporting measure of team performance was given to first-year engineering students to examine their ability to effectively interact with team members. The effectiveness of their team experiences was evaluated using a comparison of the students' responses to two surveys. This analysis was performed to examine how to improve team interactions for students who find working in a team to be a difficult experience.

Background

The social aspect of dependent learning is emphasized in ABET's general engineering criteria as an important part of the design process. Shuman et al. (2005) [3] explores how the skills necessary in becoming a dependent learner are essential to solving the critical design projects that are key to engineers having a successful global and social impact, while Dym et al. (2005) [4] discussed how dependent learning skills are important in the belief in the efficacy of the team, which increases the ability of the team members to work together. In fact, Felder and Brent (2001) [5] found if the team begins to doubt their ability to complete the tasks given, they will be unable to successfully complete any task attempted.

Since difficult problems cannot be solved by one person alone, it is important for engineers, who typically are independent learners, to become more dependent in their learning style. One of the complications of being an independent learner is that they may become used to predictable problems. When independent learners are confronted with open ended problems, problems that require input from other students, this makes them uncomfortable and can lead to them having a difficult time completing the problem solving exercise. Structured team-based problem solving can be beneficial for independent learners that are working on becoming more dependent in their learning style in order to solve more challenging problems [1], [2]. Practicing dependent learning styles within an engineering course can assist the independent learners in developing the skills needed to master the most difficult of problem solving techniques. Developing interpersonal skills through structured problem solving provides the real world experience that is necessary for engineers, since working with others creates unpredictable and problematic situations that cannot be simulated or understood any other way then through experiencing them first hand.

McCullagh and Caird (1990) [6] and Lee et al. (1994) [7] explore how students are able to retain information better when they observe others learning. When others make mistakes and correct their mistakes it is not just the individual student that gains the knowledge, but others around them can also benefit. This observation assists the student in contemplating the learning process, and then applying their observations actively to their own learning process. Learning with other students is more dynamic, since how other students will approach the material cannot be predicted. In addition, Dym et al. (2003) [8] explains that this diversity in abilities leads to overall greater success in problem solving, if framed in a teaching and learning environment. It was found that when students are not only accountable to each other for the success of the project, but also accountable to each other as part of the learning process, this interdependence provides a beneficial environment for problem solving [9], [10].

These independent and dependent learning style techniques were also seen to be beneficial in a first-year introduction to engineering course [1]. According to Seat and Lord (1997) [1], it was found that it is most important to start introducing this experience in the first-year of an engineering program, since these skills will assist students in their work experiences before graduation. This provides a successful foundation to their future engineering career.

Course Framework & Study Description

A fundamental part of this first-year engineering course is teaching students that they will be trusted to solve society's problems. Prior to this course, students' introduction to engineering and problem solving may have involved more simplified problems. These problems were usually solved without the assistance of other students, to produce one solution. As practicing engineers, problems will be more complicated. Engineers are trained to solve the most difficult problems. Many times solving these problems involves not just one team, but multiple teams. Also, several design options may need to be pursued, as well as compared and contrasted, to develop a final optimized solution.

Learning how to work well in a team environment is one of the core objectives of this engineering course. There are two team-based design projects that the students complete. The first lab project consists of programming Lego EV3 robots using Simulink (MATLAB) software. The robots are programmed to use a reflected light sensor to autonomously traverse a path. In addition to travelling the path, students will need to locate, lift, and transport a load to a prescribed location. Each team of students will have created their own robot and code to complete the task assigned. The second lab project involves a choice of five projects. These projects are the solar car project, cell phone application design, the 3D printing project (Figure 1), heat exchanger design, and an industry-sponsored project. Student teams create a proposal for their desired project, and based on the merit of each team's proposal they will be placed on a final project. As part of these projects, students will also have to work effectively in multi-disciplinary teams, and write and edit engineering design reports.

Figure 1: 3D Printed Phone Case from Project #2 of a first-year engineering design course

As part of the course, students learn how to approach problem solving and the design process using creativity and brainstorming. Students learn that they need to create a safe space within their teams to develop a wide variety of unique ideas. Many creative ideas are needed, and later a long list of ideas can be limited to only the reasonable solutions that can be accomplished within the constraints of the project.

Time constraints are very important for first-year engineering students and are also emphasized in the course. Students are taught that the design process requires an open mind, and a willingness to fail. Efficient time use is important, since usually the first design solutions, or prototypes, are not the best design options and improvements must be made. As part of this first-year engineering course, students create Gantt Charts and a project management plan. This assists student in staying on track in meeting the project and course goals, and in using the course time efficiently. Their time in lab may be the only time that the whole team can meet together and have access to the lab equipment. It is also important that the team works effectively together. An ineffective team may not meet project deadlines, or produce a successful design solution. Finally, students are asked to evaluate their team members in a team evaluation survey after each project. This survey influences their final grades on both projects.

Team Assessment

To assess the success of the course in improving team performance skills, a survey was administered between the first project and the second project, and after the second project was completed. There were 303 students who participated in this team performance study, and the response rate for both surveys was 92% or 279 students.

The results of these two surveys on team performance revealed that student experiences on a team in this first-year engineering course have been positive. When the students were asked if they noticed an improvement in their team performance from the first project to the second project, 77% of the students surveyed responded affirmatively, or 215 students out of a total of 279. These results can be found in Figure 2 below.

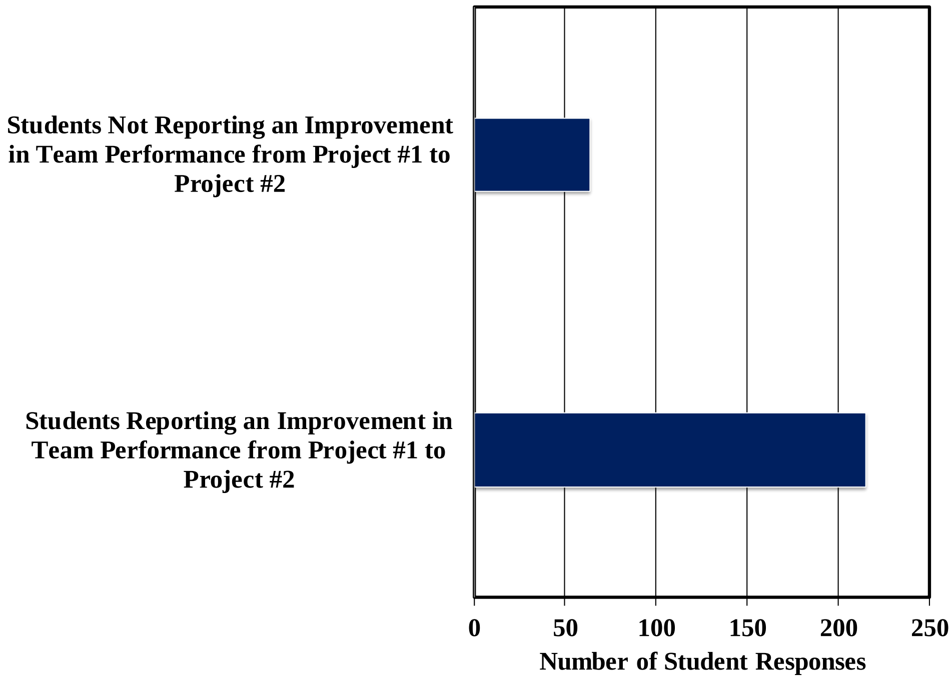

Figure 2: Number of students reporting an improvement in their team's ability to work together when comparing the performance of their team on the first project to the second project.

Again, as seen below in Figure 3, there was a positive response from the students regarding their team work preference. There was an increase in the number of students preferring to work on a team, as opposed to by themselves, with 67% of the students reporting to prefer to work in a team environment. This result in working preferences increased from 62% of the students surveyed after the first project.

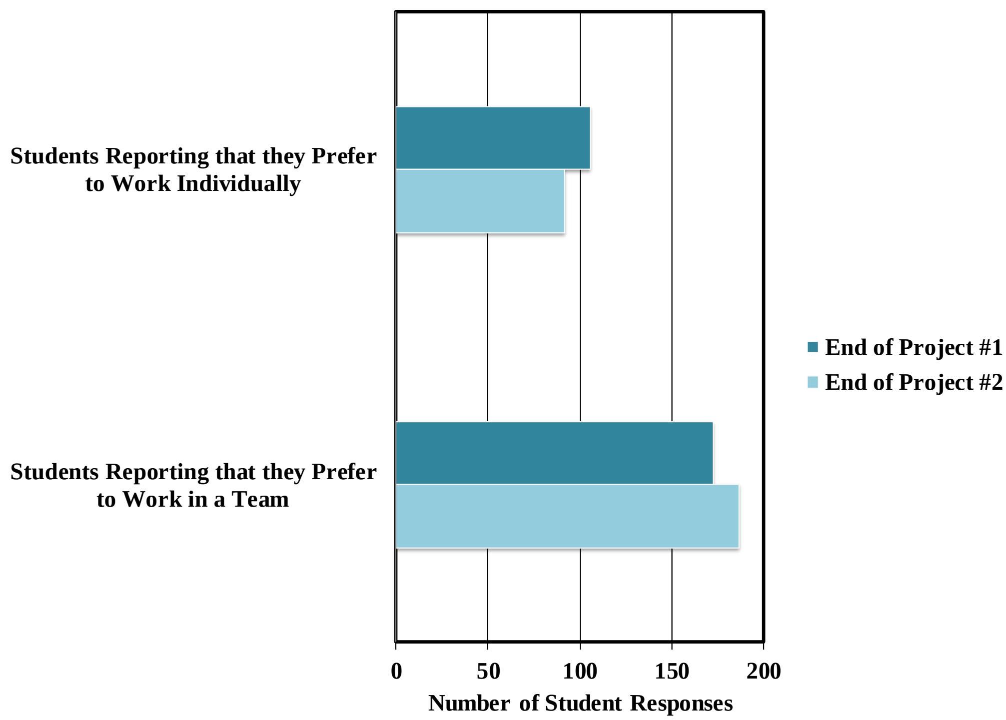

Figure 3: Number of students reporting that they prefer to work on a team, as opposed to individually, at the end of both projects.

The responses regarding students' self-appraisal of their individual team ability, when compared from before the first project began to the end of the second project, also revealed a beneficial assessment of these skills. 75% of the students reported their team ability to be good to very good in the beginning of the course, and 86% of the students reported their team ability to be good to very good at the end of the course after the second project. These reporting options were then translated to numerical values for statistical analysis of the responses. In Table 1, the students report an increase in their team abilities over the duration of the course, with 241 students out of 279 students reporting a 4.0 or higher out of a 5.0 numerical scale.

Table 1: Student self-appraisal of their individual ability to work on a team from the beginning of the first project to the end of the second project.

Answer Options	**Start of Project #1**	**End of Project #2**
Very Poor	0	0
Poor	7	3
Average	63	35
Good	114	127
Very Good	95	114
Total	279	279
Average	4.06	4.26
Standard Deviation	0.81	0.71

As part of the surveys, students were also asked to provide comments for the following three questions: (1) provide one specific example of something you learned from working with your project team, (2) what problems did you have in your project team, and (3) what would be your suggestions to improve team function and interaction. The aim was to determine the advantages or disadvantages of working as a team from the students' perspective and what the students' suggestions are to improve their team performance in the course. Example student responses to the above questions are presented in Table 2 below. As can be observed, students appreciated the importance and advantages of working as a team to improve the efficiency in problem solving and to achieve better results. Still, they raised some issues related to workload, communication, and lack of equal contribution to problem solving within the team. The noted issues, however, can be addressed by using better methodologies for team management, strengthening the connection within the team, and regular evaluation of team performance. The comparison of the survey results at the end of the first and second projects clearly indicate that the performance of the teams was enhanced due to the improvement in their communication skills and ability to work as a team. This result was also partly influenced by the team evaluation survey that is given after each project. This survey asks students to rate their team members' performance, and encourages students to improve their team performance on future team assignments.

Table 2: Student responses in terms of the advantages and disadvantages of working as a team, including their suggestions to enhance team performance in the course.

Advantages	**Disadvantages**	**Students' Suggestions**
Learned that a lot of work can be accomplished and better results can be obtained in a team	The workload done by each student may not be equal	Strengthen the connection between team members
Understood how to communicate effectively	Scheduling conflicts to meet at the same time	Assign a participation grade
Learned how to coordinate schedules with others	Occasional issues with communication and lack of trust	Define learning goals more clearly
Listened to other students' perspectives and took into account their ideas	Some students take control over every task of the project	Have a more detailed survey for assigning teams
Learned the power of working together as a team	Lack of participation of all team members	Split work evenly between every member
Improved time management and communication skills	Leadership issues	Have a mid-project check to ensure all team members contribute equally
Learned how to split responsibilities and get others to contribute more	Difficulty of trying to have all the members to work on coding at the same time	Have smaller groups so that there is an adequate amount of work for each member
Working as a team brought more creativity and ideas to the group as a whole	Had a hard time making final decisions (e.g., selecting the topic of Project #2)	Make participation in the team worth more of the project grade

Conclusion & Future Work

The future of engineering will involve increasingly more difficult problems to solve, requiring interaction with others who also have the expertise to solve these challenging problems. Unfortunately, how a student develops team performance skills is difficult to understand. Traditional methods of learning that a student has applied to mathematics and physics successfully may not be applicable when improving their interactions with others. For this reason, this method of team performance reflection was studied as a learning strategy to improve the interactions students have with their engineering peers and encourage engineering students to develop interdependent learning techniques.

Many students reported an increase in the self-appraisal of their individual team abilities. There was an improvement in the assessment of the entire team's performance as well, with the majority of students preferring to work in teams than by themselves. In the future, more work needs to be done to examine the specific impact on the students' positive team experiences, and determine how to improve the team-based activities in the course based on the feedback from the students' comments provided in the survey. This would involve looking at an examination of the students' perspective on teaming, as well as the behavioral framework the students are using to evaluate the performance of the other team members. While the fundamentals of teamwork are presented in the course, more information on assessing others in a team setting could be discussed. This further analysis needs to be done to be sure that students are making improvements in their teaming skills, and not just reporting an improvement. In addition to a closer look at assessing team performance, the formation of the teams can also be examined. Both the safe partner and the changing of teams after the first project could be analyzed to discover if there are benefits to these teaming procedures.

References

[1] E. Seat and S. M. Lord, "Enabling Effective Engineering Teams: A Program for Teaching Interaction Skills," *Journal of Engineering Education*, vol. 88, no. 4, pp. 385-390, 1999.

[2] H. A. Witkin and D. R. Goodenough, "Field Dependence and Interpersonal Behavior," *Psychological Bulletin*, vol. 84, no. 4, pp. 661-689, 1977.

[3] L. J. Shuman, M. Besterfield-Sacre, and J. McGourty, "The ABET "Professional Skills" – Can They Be Taught? Can They Be Assessed?" *Journal of Engineering Education*, vol. 94, no. 1, pp. 41-55, 2005.

[4] C. Dym, A. M. Agogino, O. Eris, D. D. Frey, and L. J. Leifer, "Engineering Design Thinking, Teaching, and Learning," *Journal of Engineering Education*, vol. 94, no. 1, pp. 103-120, 2005.

[5] R. M. Felder and R. Brent, "Effective Strategies For Cooperative Learning," *Journal of Cooperation and Collaboration in College Teaching*, vol. 10, no. 2, pp. 69-75, 2001.

[6] P. McCullagh and J. K. Caird, "Correct and Learning Models and the Use of Model Knowledge of Results in the Acquisition and Retention of a Motor Skill," *Journal of Human Movement Studies*, vol. 18, pp. 107-116, 1990.

[7] T. D. Lee, S. P. Swinnen, and D. J. Serrien, "Cognitive Effort and Motor Learning," *Quest*, vol. 46, pp. 328-344, 1994.

[8] C. L. Dym, J. W. Wesner, and L. Winner, "Social dimensions of engineering design: Observations from Mudd Design Workshop III" *Journal of Engineering Education*, vol. 92, no. 1, pp. 105-107, 2003.

[9] D. W. Jones, "Empowered Teams in the Classroom Can Work," *The Journal for Quality and Participation*, vol. 19, no. 1, pp. 80-86, 1996.

[10] J. E. Seat, W. A. Poppen, K. Boone, and J. R. Parsons, "Making Design Teams Work," *Frontiers in Education 26th Annual Conference*, pp. 272-275, 1996.