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Learning in the Laboratory: How Group Assignments Affect Motivation and Performance

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Abstract

Team projects can optimize educational resources in a laboratory, but also create the potential for social loafing. Allowing students to choose their own groups could increase their motivation to learn and improve academic performance. To test this hypothesis, final grades and feedback from students were compared for the same course in two different years, one with and one without fixed group arrangements. Seniors of the United States Military Academy at West Point were divided into groups of three or four to complete chemical engineering lab projects during the fall semesters of 2014 and 2015. In the first year, 21 cadets remained in instructor-assigned teams for the duration of the course. The next year, 23 cadets were initially assigned groups, but then allowed to choose their own teammates for the second half of the semester. There was no significant difference in graded performance between the two years, although cadet feedback was interesting. When cadets had the option of choosing groups, 65% of survey respondents strongly agreed that their peers had contributed to their learning, versus 40% when groups were not allowed to change. When asked if their motivation to learn or their critical thinking ability had increased, fewer respondents in the second year strongly agreed with either statement. While these results are not conclusive, a wider implementation of team-focused learning currently underway at West Point will offer a robust dataset and insights on how to get group work to work well in science and engineering education.

Keywords: group work, assigning teams, social loafing, motivation, academic performance

1. Introduction

1.1 Motivation and Incentives in a Group

“I hate group work”, a top performing West Point cadet told me in 2014. This is a startling remark to hear at a school that calls itself the world’s preeminent leader development institution. The student went on to say that often in courses outside of his major, he does the lion’s share of work, and the others, including non-contributors, get the same credit. As his instructor, I countered that perhaps other students are learning from him and he is learning how to work with them to accomplish a mission, a critical skill for a cadet at West Point who will become a leader in the U.S. Army. His comment made me consider how best to manage lab groups and projects in my chemical engineering course to be fair and motivate all team members to contribute. In academic group work, there is the potential problem of the free-rider, and the team usually cannot “fire” an underperforming teammate nor ensure grades are meted out fairly.

That exchange with a cadet pushed me to review what psychologists, economists, and educators have discovered about the effectiveness of learning done in groups and methods of fairly assessing group work. I wanted to know (a) if there are ways to make group performance better than individual work, (b) if groups increase student motivation to learn, or (c) if group work really works well at all. I uncovered a debate with no definitive answer on whether group or individual work produces a better outcome, but I did reach the conclusion that in a laboratory setting like my course, team projects do create a safer, more manageable learning environment. An incentive and evaluation system could help ensure fairness in settings where lab groups are the only feasible arrangement.

Once I had some background information, I implemented changes in course administration intended to create incentives for better performance by team members. I gave students the option to change groups during the course, creating the possibility for students to avoid social loafers. This might be enough of an incentive to positively affect behavior.

I continued a program already in place for providing cadet feedback from their peers, but this time the feedback was received by students who understood other opinions mattered if they wished to remain in the same group in the future. Cadet feedback offered students a way to gauge others' opinions of their performance and adjust behavior.

1.2 The Assembly Bonus Effect

Susan Cain, in *Quiet: The power of introverts in a world that can't stop talking* (2012), challenges the ideal of the extroverted leader and advances the argument that great ideas often come from introverts working in solitude. Whether teams or individuals perform better is the heart of the debate over the existence of the Assembly Bonus Effect and has implications for all group work.

On one side of the debate is a team of researchers and management educators that includes Larry Michaelsen, a firm believer that team-based learning works, and that it works much better than individual effort. Michaelsen refutes the idea that the upper limit of a team's performance is the limit of the most competent group member. He found that in 222 groups, the team outperformed the best scoring individual member 97% of the time (Michaelsen, Watson, & Black, 1989). The groups consisted of three to eight members, and the aggregate performance of these groups was better than any individual or the sum of all individual efforts. This synergistic increase is dubbed the "Assembly Bonus Effect". While Michaelsen acknowledged that other researchers have not provided empirical evidence of the Assembly Bonus Effect to corroborate his team's work, he wrote that "The lack of empirical support for the superiority of group decisions may be due, in large part, to the artificial nature of the groups, tasks, or settings in which the research has been conducted" (Michaelsen et al., 1989).

This artificiality is problematic for educators because in higher education, groups and problems are often obviously artificial and arbitrary, decided upon at the whim of the professor or teaching assistant. Michaelsen attempted to remove artificiality by presenting groups with problems that were realistic and might exist in the workplace. Participants chose solutions individually and then decided as groups how to handle situations, for which there were some answers that were more correct than others. Evaluators compared how often groups versus individuals reached expert decisions. Groups were found to do better than any individual alone. The average group score was 89.9 points out of 100, whereas the average of the best individual scores in each group was 82.6, and the average of all individual scores was 74.2 (Michaelsen et al., 1989). The scores suggest that something about working in a group causes the sum of the efforts in a team to add up to more than the individual parts, exceeding the work of the best performing individual.

Other researchers delved into the Michaelsen study and published papers addressing the study specifically to question the statistical methods used, which are critical in supporting the argument and final conclusion. Tindale and Larson (1992) found that although they could replicate the Michaelsen's results in an academic setting using quizzes and also replicate results with computer simulations based on statistics and game-theory, none of the results proved that the Assembly Bonus Effect in fact existed.

Students in the study first completed a multiple-choice quiz individually. They turned in this quiz and then assembled as a group to do the same quiz again, but as a team. The researchers found that for each question, the group as a whole never answered correctly unless at least one person got the answer correct as an individual beforehand. If no one got the answer correct before, coming together as a group did not help bring out the correct answer. Essentially, for each question, the group performance was only as good as the best individual performer. The groups performed better on the aggregate set of questions in a quiz because it was more likely that at least one member of the team knew the correct answer, but there was no evidence that collaboration alone creates synergy that bests individual efforts.

Another team of educators (Besedes, Deck, Quintanar, Sarangi, & Shor, 2012) agreed with this conclusion that teams simply aggregate existing knowledge and do not outperform any one individual within the team, but argue that this is reason enough to advocate group work. Organizing a class into teams helps spread knowledge among students and increase performance.

1.3 Grading and Game Theory

While teams can facilitate knowledge-sharing, there still remains the question of how to motivate individuals to work together and enhance learning. Researchers have shown that methods of evaluating performance affect motivation. In an article titled "Optimal Incentives for Teams", Yeon-Koo and Yoo (2001) compare Relative Performance Evaluation (RPE) to Joint Performance Evaluation (JPE). With RPE, everyone works as an individual competing for scarce resources. Promotions and bonuses are limited, and each individual is pitted against the others to succeed. In JPE, teams compete against other teams. If the team does well, everyone in the team receives the credit. This grading system ostensibly encourages cooperation, and peer pressure pushes each member to contribute utmost effort.

Yeon-Koo and Yoo present various examples where JPE helped corporations perform better, including AlliedSignal Aerospace increasing revenue by 11% after switching from RPE to JPE and Eastman Kodak decreasing production defect levels by 70% when switching to team evaluations. Based on these examples, Yeon-Koo and Yoo developed mathematical models to simulate wage incentives and performance levels, reaching the conclusion that the optimal incentive system rewards employees when members of their team do well and when work is done together, with everyone knowing how much work each member is contributing, allowing effective peer sanctioning to occur.

Yeon-Koo and Yoo's model assumes that workers can either shirk or work. Making the choice of effort level a binary option simplifies the mathematical model. When a JPE system is in place and peer sanctioning is possible (reducing wages for peers or even firing them), a Nash equilibrium that balances the optimal good of the individual and of the group exists when every member of the team works and no one shirks.

The analogy in the classroom for RPE grading would be grading on a curve. It would be in each student's interest to encourage the others to not study and to perform badly so that their own individual performance will be better rewarded. This is not best for students to learn effectively, and a workplace study supports this conclusion. Babchuk and Goode (1951) found that JPE compensation was more effective than RPE, even when incentives for collaboration and supporting other workers were incorporated into individual RPE compensation.

In Yeon-Koo and Yoo's research, peer sanctioning is an important part of the model. In my course, peer feedback allows students to assess each other's contributions to the team, and this affects a portion of each student's grade. Group members all receive the same grade for the group lab projects. This is a JPE compensation model.

1.4 Collaboration and Performance

The research by Besedes et al. shows the value of teamwork, comparing collaborative and non-collaborative teams. In collaborative groups, team members worked together, and all received the same compensation (small amounts of money in the study). In the non-collaborative group, subjects worked individually, but knew that they were part of a team and everyone in the team would receive the same compensation. The subjects did not know who else was in their team and could not see the other members working or know what the others had answered. Subjects knew that the best answer from the group would be compensated and that everyone in the team would receive the same compensation. The researchers found that the non-collaborative group members answered questions correctly less often than collaborative groups and engaged in social loafing, assuming that someone else in the group would answer the problem correctly and therefore not putting in as much effort to solve the problem (Besedes et al., 2012).

To help promote collaboration in the classroom, teams must be afforded time to actually collaborate. If the lab setting is too harried and time-constrained, cadets will likely break the assignment into parts and work as individuals and then assemble the project together at the end. While this approach has the advantage over a pure non-collaborative team in that the cadets know their individual work will be graded, it has the disadvantage of aggregate knowledge not being shared, and the team does not perform to the highest potential.

1.5 Student Views on Group Work

The student that complained to me about group work had two main points: (a) he ended up doing most of the work while others watched, and (b) he did not learn much from his peers. To expand upon this anecdotal evidence, surveys of larger student populations provide more statistically significant conclusions about student views on group work.

A team of Spanish professors teaching business administration and management decided to assess student satisfaction with teamwork after a group project, and their conclusions offer insights that apply to lab group work (Pozo-Rubio, Ruiz-Palomino, & Martínez-Cañas, 2014). The educators used surveys to determine how much time each team member said they invested, how useful the assignment was in enhancing their knowledge, and how satisfied the students were with group work. Based on student responses, the authors concluded that, "group work is a good teaching and learning tool", but also found that "there are students who shirk their responsibilities fully" (Pozo-Rubio et al., 2014). Despite free-loaders, the majority of students stated that group work increased their knowledge base and reported being happy with doing group work.

Other educators support the Spanish team's results. Questionnaire-based research by Joseph McIntyre of Auburn University (2011) found that in an introductory engineering course, students felt group interactions were more engaging than standard lectures and increased student interest in the course. Students especially enjoyed group work when the questions being answered by the team were open-ended without a definite right or wrong answer. Pfaff and Huddleston (2003) determined that (a) project grades, (b) perceived workload, (c) time allotted in class, (d) use of peer evaluations, and (e) absence of a free-rider problem are all critical indicators of how satisfied students are with group work. Perhaps not surprisingly, if grades were good, people tended to be happy about the outcome of the group work. When the task was completed in the time given during class, students were more satisfied. This relates to the work done by Besedes et al. because when students are outside of class they are more likely to work as individuals in a non-collaborative team instead of coordinating their schedules to meet outside of class.

Pfaff and Huddleston offer a simple and potentially effective way to reduce social loafing and thereby increase student satisfaction with group work: students organize their own teams for future group work. Allowing students to pick their own teams can serve as the peer sanctioning which Yeon-Koo and Yoo found necessary.

1.6 The Effect of Allowing Self-Assembled Teams on Performance

Previous research suggests that there is value to having students organized in groups so that they share knowledge, especially when working on open-ended problems. In a laboratory course, such arrangements can be a practical requirement to optimize access to faculty, equipment, and materials. In the particular case of a chemical engineering laboratory course at West Point, lab groups are a necessity and also support the institutional mission of teaching cadets how to work effectively in teams.

The work of others also shows that peer sanctioning and incentives are important to make groups function well. By assigning cadets to teams and then giving the option to choose their own teams for future team projects, I hypothesized that compared to fixed assigned groups, the cadets would (a) be more motivated to learn, (b) feel that their ability to think critically had increased, and (c) feel that their peers had significantly contributed to their learning. I also expected overall cadet grades from individual events (exams) and group project (lab reports) would improve when cadets could pick teammates.

2. Method

At the beginning of the semester in CH459, West Point's chemical engineering laboratory course, cadets were assigned to lab groups of three and four to work together on pre-lab homework and lab reports. Over 17 weeks (the fall semester), cadets spent 38 lessons in the lab designing and conducting six different experiments. There were seven supplementary class meetings for safety training outside of groups and two major individual exams. Out of 1,900 total points in the course, 900 came from group work. After each experiment, every cadet turned in a "multidisciplinary team member evaluation" (Appendix A), which anonymously provided feedback to teammates. The feedback was given to cadets in individual counseling sessions with the course director. In 2014, assigned teams were maintained for the entire course. The next year, teams were assigned for the first three experiments, but cadets picked their own groups for the last three experiments. Course feedback surveys that were already in place for both years were compared, as well as grades, to see if providing cadets the freedom to determine their own groups had any effect on motivation or learning in the course.

2.1 Characteristics of the Students, Instructor, and Institution

The United States Military Academy (USMA) is a military service academy, and all cadets are military personnel in training to become officers in the U.S. Army. To be accepted for admission to West Point, a person must be (a) between the age of 17 and 23 at time of entry, (b) single, and (c) a U.S. citizen or sponsored by an allied nation. Besides physical and medical screening requirements, an appointment must be obtained from a member of Congress, the vice president, or president. Academic requirements are typical of other highly selective academic institutions. Upon graduation, cadets are commissioned as second lieutenants. The instructor of CH459 is a military officer senior in rank to the cadets. The order and discipline of cadets is a unique feature of the student body.

CH459 Chemical Engineering Laboratory is a required course for all chemical engineering majors at West Point and is taken in the last year of their four-year undergraduate education. In the fall of 2014, there were 21 chemical engineering majors, and the next year there were 23. The cadets chose their academic majors at the start of their sophomore year, two years before taking CH459. These chemical engineering cadets comprised the total enrollment of the course, and all the cadets in the course knew each other before the course and had worked together in previous years. The cadets had never taken a course from the CH459 instructor before.

2.2 Sampling Procedures

At the end of each semester, every West Point cadet receives an email from Academic Affairs and Registrar Services (AARS) with a link to an online survey to provide course feedback. Completing the questionnaire is voluntary, and there is no incentive to do so. Cadets do this outside of class time using their own computers. In 2014, 15 of 21 enrolled cadets responded to the CH459 course-end survey. The next year, 17 of 23 cadets did so. Non-attributional data from the surveys is provided to course directors and is exempted from a separate full institutional review board review for each individual course because the survey program as a whole is reviewed according the USMA Human Research Protection Program.

2.2.1 Assigning Teams in CH459

Prior to each semester, AARS creates cadet academic schedules, balancing cadet course requirements with course offerings. There are two sections of CH459 offered in the fall each year, both taught by the same instructor.

In 2014, AARS divided the 21 chemical engineering majors into two sections of 10 and 11 cadets. In 2015, there were sections of 11 and 12 cadets. For both years, cadets in each section were ranked in order of Grade Point Average (GPA) for courses within the major, which is administrative data available to all instructors. To create three groups, cadets were arranged from lowest GPA to highest and then numbered either one, two, or three in repeating sequence to create a Team 1, Team 2, and Team 3 for both sections. This method avoids a group with only the highest or lowest academic achievers. All groups had three or four members.

2.2.2 Measures and Covariates

The USMA course-end feedback online survey includes 67 questions that cover institution and department-level topics as well as course-specific questions (Appendix B). Cadets were given a statement and instructed to select one of five possible responses: strongly agree, agree, neutral, disagree, or strongly disagree. To quantify responses, these were given point values from five to one respectively. Of the feedback survey questions, three were used to assess student motivation and learning: (a) "My fellow students contributed to my learning in this course", (b) "My motivation to learn and to continue learning has increased because of this course", and (c) "In this course, my critical thinking ability increased". USMA's Feedback Report Viewer Version 1.8, released 18 March 2000 automatically quantifies feedback, providing the mean response value and standard deviation.

Academic performance was measured by the average amount of points earned by each student out of the possible 1,900. Points were assigned solely by the instructor. Group grades were given on pre-lab homework (180 points) and lab reports (720 points). Individual events included safety training (250 points), a mid-term exam (250 points), final exam (400 points), and two sets of instructor grades based on peer evaluation feedback (50 points each). The exams were both assessments of mathematical and computer modeling skills used in lab projects.

2.2.3 Research Design

Students in 2014 and 2015 were assigned to teams and informed of their groups by both oral and written means during the first lesson. In 2015, during the introduction to the course in the first lesson, students were told that they would choose their own teams for the second half of the course. The first year, teams were kept for all six experiments. All administrative course information was available on the CH459 internal website.

Students in both years received peer evaluation feedback from the instructor in the form of one-on-one counseling sessions in a room near the laboratory. Cadets filled out multidisciplinary team member evaluation forms (Appendix A) that remained the same both years. Feedback was provided as an aggregate of other team member feedback, without indicating the identity of any individual. The instructor verbally summarized the feedback.

The online survey questions and survey format remained the same for both years. Individual graded events and the format for group projects remained the same between years. In the second year, emails to the instructor with group requests were used to note changes to groups, which were instituted for the second half of the course.

2.2.4 Experimental Manipulations

The only intentional manipulation in the experiment was the different course guidance regarding the ability to choose groups. Other changes to the course did occur, though. While the course met at the same time of day both years, the lab location changed. In 2014, the lab was on the third floor of West Point's science building, Bartlett Hall, and had windows overlooking an inner courtyard. In 2015, the lab moved to a windowless sub-basement of the same building in a newly renovated space with some new lab equipment. An actual distillation column replaced a distillation column simulator program used in the first year. Also, hydrogen fuel cell model vehicles replaced a hydrogen fuel cell stack. The homework and lab report formats and other graded requirements remained unchanged between years, however.

3. Results

Even with the option of picking teams in 2015, all the students except for one decided to stay in the same groups. The one student that moved came from a group of four and joined a group of three. Average academic performance remained nearly identical between 2014 when assigned groups were fixed and 2015 when they were alterable. Survey responses showed some variation, but with the small sample sizes, results only suggest areas for further research and do not provide statistically significant conclusions. The survey prompts with quantified response values are given in Appendices B and C.

3.1 Data Analysis

In 2014 with fixed groups, the mean grade was 1,736 points out of 1,900 (91.29%) with a standard deviation of 51 points. In 2015 with the option of picking teammates, the mean grade was 1,735 ± 50 points. These mean scores are within 0.11% of each other.

In 2014, six of 15 survey respondents (40%) strongly agreed that fellow students contributed to their learning in CH459 (Question A). In 2015, 11 of 17 strongly agreed (65%). The number of respondents that strongly agreed that their motivation to learn and continue learning had increased because of CH459 (Question B) dropped from seven to four, and the overall percentage of respondents that either strongly agreed or agreed to Question B dropped from 80% to 65%. The number that strongly agreed that their critical thinking ability had increased (Question C) dropped from eight to five.

This drop in self-reported motivation runs counter to what was expected; however, with such small sample sizes (15 and 17 respondents), it would be difficult to reject the null hypothesis and confirm that either allowing or prohibiting self-assembled groups had any effect on student motivation or learning. Jacob Bernoulli's law of large numbers requires a larger sample size and more significantly distinct results to make a sound conclusion (Bolthausen & Wüthrich, 2013).

3.2 Participant Flow

All students who began the course in 2014 and 2015 remained in the course for the entire semester, and all had equal access to the online survey. There were no changes to the student body to affect student grades.

3.3 Manipulation Fidelity

Emails received from lab groups at the end of the first half of the fall 2015 course confirm that all students in the course understood the instructions and chose their groups for the second half of the class.

4. Discussion

When beginning this research, a factor that was not well considered was the degree to which cadets would actually change lab groups. The fact that only one cadet moved groups came as a surprise. This does not change the validity of the study because the option to change groups was the experimental manipulation being tested, and that option was available to all cadets in 2015, though not widely exercised.

Changes to the lab setting and two projects did not show any significant effect on student motivation or performance. No significant changes in these areas were observed, and this is a result of having small sample sizes. This problem of resolution will likely not be a factor in future work.

In the fall of 2015, West Point overhauled its CH101 general chemistry course, a class that all cadets must either take or validate with a written examination. The new course design organizes cadets into teams, and these teams work through chemistry educational materials and solve chemistry problems together. This is a departure from previous years when class time was divided between instructor lecture and individual student work done on chalkboards. This new course offers the ability to collect information on group work and team arrangement methods with over 1,000 cadets in the first year of implementation. This robust dataset will give clear answers on best practices for group work, and shed light on whether or not any of the trends in the CH459 survey data are meaningful indicators of how the option for teams to self-assemble affects motivation and learning in a science education environment.

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Appendix A

Multidisciplinary Team Member Evaluation

The feedback form asks for the name of the person filling out the form and the name of the person being evaluated. The evaluator grades (a) technical competence, (b) communication, (c) organization, and (d) teamwork on a scale of one to five, where one designates "needs improvement", three means "meets expectations", and five is "exceeds expectations". There is a space for written comments.

Appendix B

CH459 Course-End Feedback Survey

Of 67 prompts, these three from the CH459 survey were used in this research:

Question A: My fellow students contributed to my learning in this course.

Question B: My motivation to learn and to continue learning has increased because of this course.

Question C: In this course, my critical thinking ability increased.

Response Options: [5] Strongly Agree, [4] Agree, [3] Neutral, [2] Disagree, [1] Strongly Disagree

Appendix C

CH459 Survey Responses

There were 15 respondents in 2014 and 17 in 2015. There were no skipped questions.

Response: Strongly Agree [5], Agree [4], Neutral [3], Disagree [2], Strongly Disagree [1]

Question A, 2014:	[5] x 6	[4] x 6	[3] x 2	[2] x 1	[1] x 0	Mean = 4.13 ± 0.88
Question A, 2015:	[5] x 11	[4] x 5	[3] x 0	[2] x 1	[1] x 0	Mean = 4.53 ± 0.78
Question B, 2014:	[5] x 7	[4] x 5	[3] x 2	[2] x 1	[1] x 0	Mean = 4.20 ± 0.91
Question B, 2015:	[5] x 4	[4] x 7	[3] x 4	[2] x 2	[1] x 0	Mean = 3.76 ± 0.94
Question C, 2014:	[5] x 8	[4] x 6	[3] x 1	[2] x 0	[1] x 0	Mean = 4.47 ± 0.62
Question C, 2015:	[5] x 5	[4] x 10	[3] x 2	[2] x 0	[1] x 0	Mean = 4.18 ± 0.62