

AC 2007-2721: SPONTANEOUS GROUPS VERSUS LONG-TERM TEAMS: AN INVESTIGATION USING COMPLEX PROBLEM SOLVING IN A FIRST-YEAR ENGINEERING COURSE

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Spontaneous Groups versus Long-Term Teams: An Investigation using Complex Problem Solving in a First-Year Engineering Course

Abstract

ABET requires that engineering graduates be able to work on multi-disciplinary teams and apply mathematics and science when solving engineering problems. One manner of integrating teamwork and engineering contexts in a first-year foundation engineering course is through the use of Model-Eliciting Activities (MEAs) – realistic, client-driven problems based on the models and modeling theoretical framework. This study looks at the quality of student team solutions to Model-Eliciting Activities and team effectiveness, specifically interdependency (cooperation among team members to accomplish a task), goal-setting (team sets outcome goals and sub-goals to accomplish tasks), and potency (shared belief that team members can accomplish their goals) when teams were spontaneously formed versus teams that had been working together previously.

Background

Teaming and group work in engineering education are becoming more common. Agencies like The National Research Council Board on Engineering Education, NSF Engineering Education Coalition Program, and the Accreditation Board for Engineering and Technology¹ Engineering Criteria 2000 have been instrumental in this curriculum shift. As engineering instructors become more comfortable implementing student collaboration in the classroom, questions begin to arise regarding which is the best framework for organizing this collaboration. This study begins to address the question of whether to use long-term teams or adhoc groups. The specific research question guiding this study is: *How do student groups perform on model-eliciting activities if the groups are assembled spontaneously versus long-term assignments?*

For the purposes herein, it is important to distinguish between a “team” and a “group.” For a collection of people to be a team requires that a diverse set of individuals come together as a cohesive unit with a common goal. Guzzo² defines teams as “*a group that consists of individuals who see themselves and are seen by others as a social entity, which is interdependent because of the tasks performed as members of a group. They are part of the educational process, performing tasks that affect both individual and group learning.*” Research has identified the theoretical construct for effective teams in terms of interdependency, goal setting, and potency. Teams that demonstrate *interdependency* have cooperation among team members to accomplish a task². *Goal setting* is the ability of a team to set goals and sub-goals to accomplish a task³, and *potency* is the shared belief by a team that they can be effective⁴. These characteristics distinguish “teams” from the broader term “groups.” By working cooperatively using teaming theory as a guide for skill development, students can be motivated toward the goal of performance on problem-solving tasks⁵.

Implementation

The educational setting for this study is a first-year introductory engineering course at Purdue University, Engineering Problem Solving and Computer Tools (ENGR 106), which focuses on

engineering computer tools such as MATLAB[®] and Excel[®], fundamental engineering concepts, and problem solving. Successful completion of ENGR 106 calls for students to: develop a logical problem solving process which includes sequential structures, conditional structures, and repetition structures for fundamental engineering problems; translate a written problem statement into a mathematical model; solve fundamental engineering problems using computer tools; and work effectively and ethically as a member of a technical team. Students in ENGR 106 are exposed to problem solving mainly through the implementation of model-eliciting activities.

The Accreditation Board for Engineering and Technology¹ states in Criterion 3d that students must demonstrate “an ability to function on multi-disciplinary teams.” For this reason, ENGR 106 is designed to use teams extensively throughout the course. Early in the semester, students learn about characteristics of effective teams such as interdependency, goal setting, roles and norms, cohesiveness, and communication. The students participate in team and peer evaluations of their teaming experiences and create team specific codes of cooperation that guide team functioning.

The course is structured with two fifty-minute lectures per week and a two-hour computer laboratory meeting. The students are assigned to a three or four person team starting in week 3 of the semester and remain with that team through week 7 of the semester. Students are assigned to a different team starting in week 8 of the semester. Students are placed on teams by teaching assistants with the use of guidelines that assure diversity in terms of self-evaluation of computer and programming skills, and placement of females and international students so that these underrepresented groups are not isolated. Teams are asked to work together on a weekly basis in lecture, laboratory, and outside of class for team assignments. Although this study concentrates on team performance and functionality during problem solving tasks called Model-Eliciting Activities, it is worth noting that the students are doing many other assignments in these teams.

Model-Eliciting Activities Overview

Model-Eliciting Activities are open-ended, client-driven, realistic problems that require teams of students to solve them. These authentic assessment⁶ tasks are complex, open-ended problems set in a realistic context with a client. Solutions to MEAs are generalizable procedures which reveal the thought processes of the students. The activities are such that the students work in teams of three to four students to express their mathematical model, test it using sample data, and revise their procedure to meet the needs of their client. The framework that guides the development of MEAs is based on six design principles. The theory behind these design principles has its root in engineering design. Lesh, et al.⁷ and Diefes-Dux, et al.⁸ offer more information about these design principles.

The format of a Model-Eliciting Activity is such that the students are first introduced to the context through an advanced organizer. In this case, an advanced organizer is a definition and a newspaper article that help students enter into the problem. The organizer includes questions to help students individually begin to think about the situation in which they are being placed or assist them in organizing their mathematical understandings in a manner that will be advantageous to them as they work on the engineering task. Moore, et al.⁹ and Diefes-Dux, et al.⁸ provide more information about the framework and development of these team activities.

The problem statement introduces students to the task. It is written in such a way as to make the students define for themselves the problem a client needs solved. The students must assess the situation to create a plan of action to successfully meet the client's needs. The problem solving session requires that a group of students go through multiple iterations of testing and revising their solution to ensure that their procedure or algorithm will be useful to the client⁷. By carefully crafting each MEA, students are given just enough information to make informed decisions about when the client's requirements have been met. One of the main differences between this type of task versus typical engineering problem solving activities is that most traditional problem solving activities are focused solely on the creation of a physical product; whereas, MEAs are directed at the development of procedures or processes for solving the problem⁸.

Due to the nature of the problem statement, teams of students solve the problem to meet the client's needs. The teams are necessary for two reasons. First, there is a time constraint on the solution of the problem. Therefore, students do not have the luxury of mulling over the task for hours to think of things they might have missed. By requiring multiple perspectives, the teams come to better solutions in less time¹⁰. Also, engineers working in industry often must rely on the expertise of team members to complete tasks assigned to them. Being able to effectively work in teams is not a skill that most people automatically possess. Therefore, it is necessary to put students in situations where it is essential to work in teams to allow them to develop teaming skills¹¹.

Tire Reliability MEA

The Model-Eliciting Activity that will be discussed throughout this paper is called *Tire Reliability* and was the second of four MEAs first-year students completed during the fall semester of 2005. An abbreviated version of the *Tire Reliability* MEA is shown in Table 1. The MEA was completed in a computer laboratory setting with the students working both individually and in teams of 3 to 4 students. The students had approximately twenty minutes to do the individual portion and one hour to complete the team portion of the MEA. The students begin by reading the entire MEA individually. When students work this problem, the individual questions require that the students think about the problem and provide the students time to organize their thoughts before setting out to solve the problem with their team members. The student teams then read the problem statement and develop the model for their procedure.

Table 1. Tire Reliability MEA

Individual Advanced Organizer
<p>Reliability: Reliability can be thought of as dependability, so a reliable product is one that will perform adequately for a certain period of time without failing. It might be easy to confuse quality and reliability, but they are not the same. Quality refers to a product meeting the requirements at the end of its creation process; so quality can be easily measured by the number of completed units that meet specifications. Reliability, on the other hand, looks at how many products still meet specifications and are able to perform throughout an appropriate lifespan of use.</p> <p>Why is reliability important? Every day, we depend on a lot of different products. Their inability to perform may cause us inconveniences. Sometimes, as in the case of heavy machinery or health equipment, failures might cause harmful accidents or deaths. From a company's point of view, having products that constantly fail leads to customer dissatisfaction, which leads to a bad reputation and loss of customers. This means that companies today need to constantly control their reliability.</p>

Peterson Tires in Trouble – Is This a New Firestone Case?

AP - In August 2000, Firestone announced a recall of 6.5 million tires after it became known that the tires had a higher than average rate of failure, and in 2001, Ford offered to replace 13 million Firestone tires. Since then, federal investigators documented approximately 200 deaths and 700 injuries from accidents involving the tires. The treads on the tires had a tendency to separate from the other layers. Similarly, Peterson Tires has received complaints

because of accidents caused by their tires. Company representatives say they have hired independent consultants to help them determine if they have a reliability problem. If that is the case, they would be facing any tire company’s worst nightmare: experiencing their own “Firestone recall”. The good news in all of this is that they are investigating the issue right away, so if a reliability problem exists, they will hopefully be able to fix it before any more accidents occur.

Individual Questions

Read the Memo on the previous page individually. Answer the following questions individually.

- a. Why is reliability important? Besides recalls, what kinds of consequences could a company with reliability problems experience?
- b. Give two specific examples of products, other than those mentioned, where reliability is important.
- c. A "reliability curve" shows the total number of products that have failed versus time. Describe what this curve might look for a product such as tires.

Problem Statement

TO: ENGINEERING TEAM
FROM: MORGAN PETERSON, MANAGER, PETERSON TIRES, INC.
SUBJECT: TIRE RELIABILITY

Our company has been successfully producing tires for several years. We know that tire failures can be a safety hazard, causing accidents and deaths, so we always do our best to make sure our tires are reliable. In addition, maintaining high product reliability is a priority because we have seen the negative impact problems in this area have had on other companies.

Due to several customer complaints we have received in the last few months, management has become concerned about our tire reliability. If these are isolated, independent failures, there is not much to be done. However, if there is a reliability problem, then we will have to take action to resolve the problem. This is where we will need your help.

We would like your team to provide us with a procedure to determine whether a set of data regarding tire performance is demonstrating acceptable reliability. Acceptable reliability means that failure rates are low at the beginning of a tire’s useful life and increase with time. Since we are interested in continually checking reliability, your procedure should be general, allowing our company to use it on different sets of tire data.

Attached, you will find a set of data which we know has an acceptable reliability. It consists of 1000 pieces of data representing the time (in days from installation) it took for a tire to fail and corresponds to a tire of treadwear grade 25. Treadwear grade (TG) is a measure of a tire’s durability, so a tire with TG 50 lasts twice as long as one with TG 25.

We are also supplying your team with three sets of failure data demonstrating unknown reliability from a TG 50, TG 100, and a second TG 25 tire lot.

We are asking your team to provide us with a generalizable procedure to analyze the reliability of the tires from the provided data. We are also asking you to use your procedure to determine if the three types of tires corresponding to the data sets attached have acceptable reliability and if the results show that the tires have the correct treadwear grade.

Please keep in mind that management is extremely concerned about this situation, so your procedure and results should be concrete and understandable, as it will have a significant influence on the future direction of the company.

We look forward to receiving your response.

Morgan Peterson

Final Instructions

You should work with the team assigned by your TA. Before you start this task, select one team member to be the

Timekeeper, another to be the Recorder, another to be the Meeting Coordinator, and one to be to be the Encourager/Gatekeeper. Once you have decided on the role of each member for this lab session, begin working on this task with all members of your team working at one computer.

The team Timekeeper should monitor the time spent on tasks. Keep in mind the estimated completion time. The team Recorder should serve as the initial keyboard operator.

1. Within your team, compare your answers to the individual questions. If there are different responses, your team must come to consensus on what the answers should be.
2. Reread the memo sent to your team from Morgan Peterson. Make note of all specific directions given to your team to successfully complete this task.
3. Morgan Peterson has provided tire data. This data can be found in the Excel Spreadsheet.
4. Write the body of a memo to Morgan Peterson that includes:
 - A reusable procedure to determine whether a set of data regarding tire performance is demonstrating acceptable reliability.
 - The results of applying your reliability procedure to the three sets of tire data provided (Do they have an acceptable reliability? Do the results show the tires have the correct treadwear grade?)

Be sure to Submit your team's work when you are finished.

Data Collection and Instruments

To assess whether or not there is a difference in performance between temporary groups and long-term teams, a control experiment took place. Students in all ENGR 106 laboratory sections were assigned to teams for extended periods of time. When teams perform a model-eliciting activity, the team members have established accountability toward one another. Teams are a very special kind of group. According to Guzzo², “a team is a group of individuals who see themselves and are seen by others as a social entity, which is interdependent because of the task performed as members of a group.” The main difference between groups and teams is interdependency.

How do student groups perform on model-eliciting activities if the groups are assembled spontaneously? To investigate the differences between temporary groups and long-term teams, a control group for this study was designed. To answer this question, one laboratory section of ENGR 106 performed the *Tire Reliability* MEA with newly formed groups that were maintained only for that laboratory period. There were four types of data collected for this study. First, the team solutions for the MEA were collected electronically. The solutions were then graded by the researcher using a scoring rubric called the *Quality Assurance Guide* (Table 2). Second, for the teams analyzed in this study, the researcher and the TA rated the team functioning using the *TA Observation Tool* (Table 3). Immediately following the conclusion of the MEA, the students individually completed an online survey called the *Team Effectiveness Tool* (Table 4), and later completed the MEA Reflection Tool (Table 5).

The quality of the student team solution is rated using a rubric called the *Quality Assurance Guide* (Table 2) which assesses whether teams fully met the client’s needs. It is based on a five point scale where five corresponds to “Shareable and Reusable: The solution not only works for the immediate situation, but it also would be easy for others to modify and use it in similar situations” and one corresponds to “Requires Redirection: The product is on the wrong track. Working longer or harder won’t work.”

Table 2. Quality Assurance Guide.

To prepare to assess quality of the solution (mathematical model), put yourself in the role of the client. To do this, it's necessary to be clear about answers to the following questions:

- Who is the client?
- What solution (mathematical model) does the client need?
- What does the client need to be able to do with the solution (mathematical model)?

Then, the quality of solution can be determined by focusing on the question:

How useful is the solution (mathematical model) for the purposes of the client?

Quality Score	Performance Level	How useful is the solution (mathematical model)?
1	Requires redirection	The product is on the wrong track. Working longer or harder won't work.
2	Requires major extensions or revisions	The product is a good start toward meeting the client's needs, but a lot more work is needed to respond to all of the issues.
3	Requires only minor editing	The product is nearly ready to be used. It still needs a few small modifications, additions or refinements.
4	Useful for this specific data given	No changes will be needed to meet the immediate needs of the client, but this is not generalizable to new but similar situations.
5	Sharable or reusable	The solution not only works for the immediate situation, but it also would be easy for others to modify and use it in similar situations.

The students' product should make it clear that:

- The students went beyond producing a solution that *they* themselves can use to also produce a solution that *others* can use – by including needed explanations, and by making it as simple, clear and well-organized as possible.
- The students went beyond thinking *with* the solution to also think *about* it – by identifying underlying assumptions (so that others know when the solution might need to be modified for use in similar situations)
- The students went beyond *blind* thinking to also think *about* their thinking (by recognizing strength and weaknesses of their approach compared with other possible alternatives).

The observations of the teams were done using the *TA Observation Tool* (Table 3) which allowed the researcher and the TA to rate the teams on easily observable forms of interdependency, potency, and goal-setting. The observers had space in the tool to take detailed field notes of the performance of the teams.

Table 3. TA Observation Tool.

1. Number of students engaged in MEA: _____ out of _____	<u>Notes</u> :
2. Number of students ACTIVELY participating: _____	
3. How much of the time was the team on task (goal oriented)? ALL MOST 50% SELDOM NEVER	
4. Does the team demonstrate the belief that they can be successful? _____	

Through the *Team Effectiveness Tool* (Table 4), teams rated their own performance using 26 Likert-scale items which assess interdependency, potency, and goal-setting, as well as learning.

Table 4. Team Effectiveness Tool.

Individual team members respond to this survey using Likert scale responses: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree

INTERDEPENDENCY

- My team collaborated effectively to complete our assignments.
- My contributions to the team were appreciated by each team member.
- My teammates displayed appropriate interpersonal skills when conflict arose.
- I had confidence in each team member to contribute his/her fair share of what was required.
- My team used a process/method (e.g., code of cooperation) to hold each member accountable.
- Team members were prepared for team meetings.
- Team members arrived on time to team meetings.
- At any particular time, I knew what each member of my team's role was so I knew what to expect from them.
- An outside observer would have concluded our team had an effective process to complete our assignments.

LEARNING

- The solutions of my team to course assignments were better than what I would have done on my own.
- This team helped me understand the material presented in this course.
- Working on this team made me realize some things about myself (e.g., communication ability, leadership) that I was not aware of.
- This team enabled me to acquire the skills necessary to contribute to working on future teams.
- This team enhanced my academic learning.

POTENCY

- My team was confident in its ability to overcome adversity (e.g., interpersonal conflict, assignments).
- I feel a sense of accomplishment in my team's ability to work together.
- This team gave me confidence in the ability of teamwork to solve problems.
- My team had the collective abilities (e.g., communication, interpersonal, technical) to accomplish course assignments.
- I was confident that our team produced acceptable solutions to course assignments.

GOAL SETTING

- This team helped me accomplish my individual goals for this course.
- My team used clear, long term goals to complete tasks.
- My team reflected upon its goals in order to plan for future work.
- My team made use of incremental goals (i.e., we set short-term goals) in order to complete course assignments on time.
- My input was used to set our team goals.

VALIDITY

- Overall, I thought being on this team was a very negative experience.
- Our team did not function well as a team; we did not establish any process to hold one another accountable nor did I ever know what individuals were responsible for.

Finally, the *MEA Reflection Tool* (Table 5) had individuals rate their own personal reflections on the team performance and MEA experience using 22 Likert-scale items and 6 open-ended responses. For the purpose of this study, only the 22 Likert-scale responses were considered.

Table 5. MEA Reflection Tool.

Individual team members respond to this survey using Likert scale responses: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree

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- My team collaborated effectively to complete our assignments.
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- I had confidence in each team member to contribute his/her fair share of what was required.
- My team used a process/method (e.g., code of cooperation) to hold each member accountable.
- Team members were prepared for team meetings.
- Team members arrived on time to team meetings.
- At any particular time, I knew what each member of my team's role was so I knew what to expect from them.
- An outside observer would have concluded our team had an effective process to complete our assignments.

LEARNING

- The solutions of my team to course assignments were better than what I would have done on my own.
- This team helped me understand the material presented in this course.
- Working on this team made me realize some things about myself (e.g., communication ability, leadership) that I was not aware of.
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VALIDITY

- Overall, I thought being on this team was a very negative experience.
- Our team did not function well as a team; we did not establish any process to hold one another accountable nor did I ever know what individuals were responsible for.

The control group was created from one section of ENGR 106. The teaching assistant from that section had been extensively trained to work with model-eliciting activities, had experience implementing them, and had been trained to write MEAs as well. The control group consists of eight teams that were assembled for the sole purpose of completing *Tire Reliability* MEA during one laboratory session in Week 6 of the semester. After the completion of this MEA, these students resumed working with their long term teams that had been set up in Week 3 of the semester.

The experimental group was chosen from another teaching assistant who has been extensively trained to implement and write MEAs. This choice was to reduce bias from the difference in teaching assistants. The experimental group also consists of eight teams – six teams from one section and two from another. Missing data prevented using all eight teams from the same section.

Data Analysis

Qualitative methods were used to analyze the data from the student team solutions to the MEA. Using the *Quality Assurance Guide* (Table 2), the qualitative data from the team solutions to the MEA were scored, therefore providing quantitative data. The solutions of the sixteen teams were assessed by the lead researcher and an outside researcher to ensure reliability. Here inter-rater reliability was 75% Cohen's Kappa^{12,13} agreement for all 100 teams assessed for the *Tire Reliability* MEA. Values of 65% or higher are considered acceptable levels of intercoder agreement using Cohen's Kappa¹⁴. When there were discrepancies, the observer and the outside researcher came to consensus on the team score for the MEA.

To validate the observer scores for the *TA Observation Tool* (Table 3), the lead researcher and the teaching assistant both took observations of the eight control teams for this study. The Pearson Product-Moment correlation coefficient for the observations was 0.773 which is statistically significant with a p-value of 0.024. This is a *marked degree of correlation*¹⁵. The cutoff for a *high degree of correlation* is 0.8, so this correlation is very good for such a small N.

Quantitative methods for analyzing data were applied to the data from the *Team Effectiveness Tool* (Table 4) and the *MEA Reflection Tool* (Table 5). In order to analyze the 26 Likert-Scale items from the *Team Effectiveness Tool* and the 22 Likert-scale items from the *MEA Reflection Tool*, an internal reliability test, Cronbach's coefficient alpha, was run using the results from all student responses from the course on this MEA. Here Cronbach's coefficient alpha for the *Team Effectiveness Tool* was 0.968 (N=1106) and for the *MEA Reflection Tool* was 0.864 (N=1167). These values exceed the necessary level of 0.80 which is considered very good for reliability. These instruments have been found to have validity in previous studies¹⁶⁻¹⁹. For each team, the sum scores from the individuals were averaged into team sum scores for use in this study.

The Wilcoxon signed-rank test was used to analyze the data for the two groups. This test is the non-parametric version of the 2 independent samples t-test, which means the test is appropriate when you want to conduct a 2 independent samples t-test, but the dependent variable is not normally distributed. The data here was analyzed using SPSS® which reports the z-score and p-value for the sets of data.

There are four sets of data for each set of teams: MEA performance as graded by the *Quality Assurance Guide* (Table 2) and three measures of team functioning (*TA Observation Scores* (Table 3), *Team Effectiveness Scores* (Table 4), and *MEA Reflection Scores* (Table 5)). The Wilcoxon signed-rank test was used to compare the ratings of the control group versus the experimental group for each instrument. The raw data for the control group is listed in Table 6 and for the experimental group in Table 7.

Table 6. Raw data for the control group scores on each data collection instrument

Team Identifier	MEA Score	Observer Score	Team Effectiveness Score	MEA Reflection Score
A	1	2.8	3.9	3.7
B	2	3.4	4.1	3.5
C	2	3.4	4.5	4.0
D	2	4.0	3.4	3.4
E	3	3.6	3.6	3.4
F	3	3.7	3.6	3.6
G	3	3.9	4.4	3.9
H	3	4.0	4.5	3.6

Table 7. Raw data for the experimental group scores on each data collection instrument

Team Identifier	MEA Score	Observer Score	Team Effectiveness Score	MEA Reflection Score
1	1	3.7	4.0	3.5
3	2	3.8	4.1	3.5
2	2	3.8	4.2	3.1
4	3	3.8	3.4	3.0
5	3	3.8	4.3	3.6
7	4	3.8	4.3	3.6
6	4	4.0	3.8	3.6
8	4	4.0	4.6	3.5

For each of the paired tests, the hypothesis test is as follows:

H_0 : The medians of the Experimental and Control Groups for the instrument are equivalent.

H_a : The medians of the Experimental and Control Groups for the instrument are not equivalent.

Rejection of the null hypothesis comes when the differences between the medians are statistically significant. This is a two-tailed test of significance.

Results and Discussion

The research question “How do student groups perform on model-eliciting activities if the groups are assembled spontaneously versus assigned?” is analyzed by examining the student team scores and the team functioning measures on the MEA in the experimental group and in the control group. Table 8 contains the means and medians of the test groups for each of the treatments, and Table 9 contains the z-score and p-value for each test.

Table 8. Comparing teams' scores by means and medians in the control group (C) and experimental group (E)

Instrument		Mean	Median
MEA Score from the <i>Quality Assurance Guide</i> **	C	2.4	2.5
	E	2.9	3.0
TA Observation Score*	C	3.6	3.7
	E	3.8	3.8
Team Effectiveness Score	C	4.0	4.0
	E	4.1	4.2
MEA Reflection Score*	C	3.6	3.6
	E	3.4	3.5

** Difference is significant at the 0.05 level (2-tailed).

* Difference is significant at the 0.1 level (2-tailed)

Table 9. Z-scores and p-values for Wilcoxon Signed-Rank test on the control group vs. the experimental group

	MEA Score	Observer Score	Team Effectiveness Score	Reflection Score
Z-score	-2.000 ^a	-1.784 ^a	-0.738 ^a	-1.682 ^b
Significance (2-tailed)	0.046	0.074	0.461	0.093

a Based on positive ranks.

b Based on negative ranks.

MEA Scores

The medians of the Control Group versus the Experimental Group are 2.5 and 3.0, respectively. The Z-score is -2.00 based on the positive ranks with $p=0.046$. The statistical significance allows for the rejection of the null hypothesis in favor of the alternative hypothesis. Since the medians are significantly different, this suggests that the teams that have been together for a longer period of time and have accountability toward one another are more likely to perform better on an MEA than groups that have been formed only for the duration of the activity.

TA Observer Scores

The TA Observer Scores have medians of 3.65 and 3.80 for the Control Group and Experimental Group, respectively. When comparing these groups, the Wilcoxon Z-score is -1.78 based on the positive ranks with $p=0.074$. Again, this statistical significance allows for the rejection of the null hypothesis in favor of the alternative hypothesis. The alternative hypothesis states that the medians are statistically different from one another. With the validity of the TA observations checked by the correlation study, this finding suggests that students are functioning better as

teams when they have been together for a longer period of time and have had accountability than when they are put in groups only for the duration of the model-eliciting activity.

Team Effectiveness Scores

The medians of the *Team Effectiveness Tool* Scores for the control group and the experimental group are 4.00 and 4.15, respectively. With a Z-score of -0.74 and p-value of 0.461, this test does not reject the null hypothesis. The failure to reject the null hypothesis does not prove that the medians are statistically the same, but there is not enough strength to reject that idea either. This is another measure that suggests that our students are not successfully rating their own team performance.

MEA Reflection Scores

The results for this section are not what were expected. The MEA Reflection Scores have medians of 3.6 and 3.5 for the control group and experimental group, respectively. When comparing these groups, the Z-score is -1.68 based on the negative ranks with $p=0.093$. This statistical significance allows for the rejection of the null hypothesis in favor of the alternative hypothesis. However, the general consensus had been that the experimental group would score higher in each of the four measures. Here, the control group has the higher median.

The results of this study emphasize the importance of ensuring that teams are interdependent entities with accountability toward one another. This study has shown that teams of students that have been working together for a longer period of time and have individual accountability to the team are more likely to perform better on the MEA and be better functioning teams as defined by interdependence, goal-setting, and potency.

The study has also verified previous findings regarding students' self-reports of team functioning. The results from the *TA Observer Scores* verify that the experimental group was more likely to function better on teams than those in the control group. However, the results from the Team Effectiveness Scores show that the students in both groups were not statistically different. The students are having trouble correctly identifying their own teaming abilities and functioning. This result is in line with previous research results with the *Team Effectiveness Tool*^{16,18}.

One of the most surprising results of this study was the statistically significant difference in the *MEA Reflection Scores*. The medians for this set of data suggest that the control group had better attitudes toward the MEA than those of the experimental group. This may be due to the fact that the students in the control group were told why they were being switched into different teams for the activity. The students may have found some intrinsic reward for being "chosen" for the research that was being conducted. This finding could suggest that even though attitudes are important to the problem solving process, the team effectiveness as defined by interdependence, goal-setting, and potency is a much more important factor in performance. This also may be due to the fact that the newly formed groups did not know each other yet, so the members had not yet developed any negative relationships. The groups may have not begun to go through normal team processes due to lack of time.

Conclusions and Future Directions

Teams that have longevity perform better on MEAs than adhoc teams. This study showed that teams that had been working together for several weeks performed better on the *Tire Reliability* MEA than did the teams that were spontaneously put together for that day only. When educators are implementing MEAs into the classroom, care must be taken to form teams well and allow them time and opportunity to grow into a functioning team. The instructors of courses with curricula heavy in teaming that have must have more extensive training on implementing teams in their classrooms. Extensive research has taken place to help educators know how to implement teams in to the classroom. The book *Active Learning: Cooperation in the College Classroom*²⁰ is a good example of a resource that educators can use to help them with team implementation strategies and help students become better team members. It develops the understanding of why teams are important for student achievement including increasing students' effort to achieve and the promoting of positive relationships among students and their good psychological health. The book also iterates the basic elements of teams that educators must be aware of and teach to their students. These elements are positive interdependence, individual accountability, promotive interaction, social skills, and group processing.

The results of this study could be used to begin to show that engineering student teams that have longevity perform better on a wider collection of team-based activities. In order to further the understandings in this area, more studies like this one are needed in different contexts to verify the claims.

Bibliographic Information

1. Accreditation Board for Engineering and Technology, *Criteria for Accrediting Programs in Engineering*, Baltimore, MA: ABET, Inc., 2003.
2. Guzzo, R. A. "Group Decision Making and Group Effectiveness," In Goodman, P. S. (Ed.), *Designing Effective Work Groups*, 34-71, San Francisco, CA: Jossey-Bass, 1986.
3. Locke, E. A., & Latham, G. P. , *A Theory of Goal Setting and Task Performance*, Cliffs, NJ: Prentice Hall, 1990.
4. Guzzo, R. A., Yost, P. R., Campbell, R. J. & Shea, G. P., "Potency in Groups: Articulating a Construct," *British Journal of Social Psychology*, 31, 87-106, 1993.
5. Barak, M., & Maymon, T., "Aspects of Teamwork Observed in a Technological Task in Junior High Schools," *Journal of Technology Education*, 9(2), 4-18, 1998.
6. Wiggins, G., *Educative Assessment: Designing Assessment to Inform and Improve Student Performance*. San Francisco: Jossey-Bass, 1998.
7. Lesh, R. A., Hoover, M., Hole, B., Kelly, A., & Post, T., "Principles for Developing Thought-Revealing Activities for Students and Teachers," in *Handbook of Research Design in Mathematics and Science Education* (pp. 591-645). Mahwah, NJ: Lawrence Erlbaum, 2000.
8. Diefes, H.A., Moore, T., Zawojewski, J., Imbrie, P.K., and Follman, D., "A Framework for Posing Open-Ended Engineering Problems: Model-Eliciting Activities," *Frontiers in Education Conference*, Savannah, GA., 2004.
9. Moore, T. and Diefes, H.A., "Developing Model-Eliciting Activities for Undergraduate Students Based on Advanced Engineering Content," *Frontiers in Education Conference*, Savannah, GA., 2004.
10. Zawojewski, J., Lesh, R., and English, L., "A Models and Modeling Perspective on the Role of Small Group Learning Activities," *Beyond Constructivism: Models and Modeling Perspectives on Mathematics Problem Solving, Learning, and Teaching*, Mahwah, NJ: Lawrence Erlbaum, 2003.

11. Smith, K. A., *Teamwork and Project Management*, New York, N.Y.: McGraw-Hill. BEST Series, 2004.
12. Cohen, J., "A Coefficient of Measurement for Nominal Scales," *Educational and Psychological Measurement*, 20, 37-46, 1960.
13. Cohen, J., "Weighted Kappa: Nominal Scale Agreement with Provision for Scaled Disagreement or Partial Credit," *Psychological Bulletin*, 70, 213-220, 1968.
14. Harris, J., Pryor, J., and Adams, S., "The Challenge of Intercoder Agreement in Qualitative Inquiry," Unpublished Manuscript, University of Texas at Austin, 1997.
15. Franzblau, A., *A Primer of Statistics for Non-Statisticians*, Harcourt, Brace & World, 1958.
16. Imbrie, P.K., Maller, S.J., and Immekus, J.C., "Assessing Team Effectiveness," *Proceedings from the American Society for Engineering Education Annual Conference*, Portland, OR, 2005.
17. Moore, T.J, Diefes, H.A., and Imbrie, P.K., "Model-Eliciting Activities: A Curricular Tool to Measure First Year Engineering Students' Perception of Learning Problem Solving and Teaming," *Frontiers in Education Conference*, Indianapolis, IN, 2005.
18. Moore, T.J, Diefes, H.A., and Imbrie, P.K., "Assessment of Team Effectiveness During Complex Mathematical Modeling Tasks," *Frontiers in Education Conference*, San Diego, CA, 2006.
19. Moore, T.J, Diefes, H.A., and Imbrie, P.K., "Quality of Solutions to Open-Ended Problem Solving Activities and Its Relation to First-Year Student Team Effectiveness," *American Society for Engineering Education Annual Conference*, Chicago, IL, 2006.
20. Johnson, D.W., Johnson, R.T., and Smith, K.A., *Active Learning: Cooperation in the College Classroom*, Edina, MN: Interaction Book Company, 1998.