Peer-led team learning in mathematics courses for freshmen engineering and computer science students

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Abstract

Peer-led Team Learning (PLTL) is an instructional method reported to increase student learning in STEM courses. As mathematics is a significant hurdle for many freshmen engineering students, a PLTL program was implemented for students to attempt to improve their course performance. Here, an analysis of PLTL for freshmen engineering students in mathematics courses over three years is presented. The particular issue of concern is if a student's performance in their mathematics courses improves significantly with frequent participation in PLTL groups.

Student performance in their mathematics course was evaluated through course grades. The level of participation by the students in their PLTL groups was determined through weekly attendance reports, with mentors assuring that all students participated fully while present. Grade comparisons were made both between participants who attended different numbers of group sessions and between participants and non-participants in their courses.

Analysis of the students in the program suggests that increased participation in the PLTL groups correlates to better course performance. Data indicate that statistically significant subject mastery is achieved by PLTL participants in Calculus I courses. However, while Pre-Calculus level students show some improvement, the results are not consistently statistically significant. In general, it is found that greater participation in PLTL groups is beneficial for many students. PLTL groups offer educational benefits to many students, but participation does not guarantee improvements for all students.

Keywords: *peer-led team learning, freshmen engineering, college algebra, Calculus, engineering math*

1. Introduction

Peer-led Team Learning (PLTL) is an educational technique developed initially for Chemistry courses that is designed to enhance student learning of the subject matter by fostering interaction between students in the course as they help each other to learn (Gosser 2011). The technique has subsequently been demonstrated to be successful in a variety of STEM disciplines courses (Baez-Galib et al. 2005; Hockings et al. 2008; Horwitz et al. 2009; Lewis and Lewis 2005; Lewis 2011; Lyle and Robinson 2003; Lyon and Lagowski 2008; Preszler 2009; Tien et al. 2002; Wamser 2006). While there are more reported results available for science courses, researchers have shown that the technique can be successful in mathematics and engineering courses as well. For example, Liou-Mark et al. (2010) applied PLTL methods to PreCalculus courses, and found that considerable improvement in the performance of participating students was gained. Loui and Robbins (2008) and Loui et al. (2009) used PLTL in freshmen electrical engineering courses, and found that students with regular attendance at the sessions performed much better on their final exams in some, but not all, semesters. Furthermore, qualitative responses indicated additional benefits for the students, such as fostering a greater sense of belonging among the students. Overall, Gosser (2011) found that, across a number of studies, the average percentage of students receiving a C or better in their courses was 15 percent higher for students participating in PLTL groups versus students not participating in the groups.

With this evidence in mind, PLTL groups were initiated at a large urban research university in the Midwest region of the United States in the fall 2009 semester. These groups were designed for incoming freshmen students in engineering and computer science. They were primarily organized around the students' mathematics courses. Secondarily, students in the same intended field of study were placed together in the groups when possible. For reference purposes, the courses for which study groups were used are listed in Table 1.

The general content of the courses is as follows. Math 105 covers algebraic techniques involving such topics as polynomials, exponential and logarithmic functions, conic sections, and systems of linear equations. Math 116 considers these topics at a higher level, and also considers matrices, determinants, sequences and series. The material in Math 117 includes trigonometric functions, complex numbers and polar coordinates. Math 231 is a standard first course in Calculus and Analytic Geometry, covering such topics as limits, derivatives and definite integrals. Math 232 is a standard second course in Calculus and Analytic Geometry, extending Math 231 with integration techniques, parametric equations, conic sections and polar coordinates.

The impetus behind the creation of these PLTL groups was the traditionally low graduation rate of students from engineering and computer science. For example, the fall 2004 incoming freshmen in engineering and computer science had a six-year graduation rate from these disciplines at the university of 26.3 percent. Further observations indicated that a key problem area for students entering the college was completion of their mathematics sequence. To complete their sequence, all engineering students need to complete 3 se-

Course Number	Course Name	Subject Matter Level
Math 105	Intermediate Algebra	Secondary School
Math 116	College Algebra	Pre-Calculus
Math 117	Trigonometry	Pre-Calculus
Math 231	Calculus I	First-semester Calculus
Math 232	Calculus II	Second-semester Calculus

Table 1: Numbers and names of mathematics courses taken by students in the PLTL Group

mesters of Calculus and one semester of Differential Equations/Linear Algebra, while computer science students need to complete two semesters of Calculus. In order to advance to the next mathematics class, students need to receive a grade of C or better in the previous course through Calculus II. One factor that led to the high attrition rate was the need for students to retake at least one course in their mathematics sequence. In addition, students are placed into their initial mathematics course based on the results of a mathematics placement exam. As a result, many (traditionally 50-70 percent of incoming freshmen) engineering and computer science students begin their collegiate studies at the Intermediate Algebra or PreCalculus levels. The PreCalculus courses (two separate courses in College Algebra and Trigonometry) often caused further difficulties for students as they sought to obtain grades of C or higher in each course to move into Calculus I. These factors necessitate an increase in the amount of time students spend in college as they try to receive degrees in engineering or computer science, and further increased attrition rates.

To help students achieve greater success in their mathematics courses, PLTL groups were established. Participation in the formal PLTL groups was limited to incoming freshmen engineering and computer science students. Eventually, it is hoped that these groups will increase graduation rates by (1) helping the students complete their mathematics sequence more rapidly, (2) increasing the retention of knowledge learned in their courses, and (3) creating support structures between students. As the groups were only established in the fall 2009 semester, it is too soon to determine their eventual impact on graduation rates. However, the impact of the PLTL groups on student performance in their mathematics classes can be determined.

Below, the format of the groups is described, as is a summary of the methods used to implement the groups and this includes a description of what actions were taken to increase participation. Following that, we describe our research methodology for analyzing the data and discuss the results.

2. Format and Purpose of the PLTL Groups

There are three basic formats for PLTL groups as described in Gosser (2011). The group format used here best matches their classification of a Type 3 format, where a peer-led group is treated as an additional course component rather than a required component of the course. It should be noted that these PLTL groups are not specifically connected to the mathematics course, but are independently run by the engineering college with input and some assistance from the faculty in the Department of Mathematical Sciences. This assistance is primarily in the form of providing the engineering college with copies of course syllabi and homework assignments for the relevant courses. Beyond this, the mathematics course instructors were not involved, with training and session material preparation being done by the engineering college.

The PLTL groups met once per week, for approximately one hour each session. The students in the PLTL groups were only freshmen engineering and computer science students, but the base courses for which the PLTL groups were a supplement were taken by students from other years and other disciplines. The PLTL groups were set up for each mathematics course, (but not attached to a specific section of the course), although the material from Math 116 and Math 117 were covered in a single set of PLTL groups. For the Math 116/117 PLTL groups, more time was typically devoted to Math 116 as more students take Math 116 and students tend to struggle more with the Math 116 material than the Math 117 material.

In these PLTL groups, students work together to solve appropriate mathematics problems with guidance of peer facilitators; these peer facilitators are upper-level students in the engineering college. The PLTL groups aim to develop student confidence in collaborative problem solving skills and to teach first-year college students independent problem solving skills. This procedure requires deep thought, discussion, and risk taking; these are all skills beneficial for careers in engineering and computer science. For this reason, facilitators do not have solution manuals. Facilitators work with students to solve problems methodically while encouraging critical thinking, as opposed to supplying answers to questions. The problem solving methods should carry over to their independent work.

2.1 Leader Preparation

The student facilitators were hired and then trained according to two *Peer-Led Team Learning* books: A *Guidebook* and A *Handbook for Team Leaders* (Gosser et al., 2001; Roth et al., 2001). Facilitators were hired based on their willingness to help, openness to the lecture-free format of the PLTL groups, and success of having earned a GPA of 2.7/4.0 or higher in their own college Algebra, Trigonometry, and Calculus classes. The main duty of the facilitators is to keep students working towards a solution to the problem under consideration and to keep them focused during discussions. Facilitators are taught to think of themselves as a coach rather than a teacher. Facilitators stress the idea that students will likely find greater success in their studies if they put in substantial effort. This idea is further reinforced in the students because the facilitator's very presence demonstrates that students do succeed in the college.

As role models, facilitators are expected to represent the school in a positive manner. Since the peer facilitators are in direct contact with students, they are in a position to inspire the students to succeed as they begin their college careers. To further excite the freshmen students, the peer facilitators are encouraged to engage students in discussions of more advanced engineering topics, design projects from their own courses and current events. As another part of training, they are also given advice on how to handle different personalities and learning styles. Facilitators are also taught techniques to enhance the dynamics of their groups.

Facilitators are required to prepare at least one hour per week for their groups. They are assigned two or three PLTL groups and are given the syllabus of the courses for which they will be peer facilitators. Copies of the Intermediate Algebra, ollege Algebra, Trigonometry, and Calculus textbooks are available for use by the facilitators in a central location which is accessible to the facilitators at all times. This enables the facilitators to prepare for their groups and to identify any areas which they perceive may cause difficulties for the students. They are encouraged to work out some problems to be sure that they understand the topics to be covered.

All facilitators meet once a week with the program coordinator to discuss group attendance, participation and any concerns or problems with their groups. This is a time for them to share with each other the progress of their groups and to give each other encouragement and advice. As an example, at one meeting the facilitators mentioned that students in Intermediate Algebra felt that the material was too easy to justify a PLTL group. The program coordinator suggested creating worksheets to change the format of the material in order to keep students on task. One facilitator then created a worksheet and brought back positive feedback to the other facilitators regarding its impact. Creating a five-question worksheet proved to be easy preparation for her and created a challenging objective for the group. The worksheets provided the students with insights into their weaknesses, affirming that they did need to study and that participation in the study group is worthwhile.

2.2 PLTL Group Logistics

The PLTL group logistics are designed to promote a cooperative learning environment. Unlike a typical lecture-style environment, the desks are arranged in a semi-circle with a white board available for easy use. The size of the groups range from 6-12 students, with a typical number of students being 10. The peer facilitator sits with the students, taking a position as an equal, rather than separate as an authority figure. The facilitator will open the dialogue and inquire if there are any specific problem areas from the homework and lectures. The facilitator will choose an appropriate problem as a starting point for the students, and then engage the whole group in a discussion of the problem and its solution. The problems sometimes come directly from assigned homework, but also come from additional problems in the textbook or related texts. The facilitator will provide suggestions and guidance as needed, although as the semester progresses, there is usually less need for this as the students become more comfortable with the group dynamics. The peer facilitator does not solve the problem for the students; rather the facilitator helps guide the students. Note that this format differs from that of a common alternative format of Teaching Assistant-led problem-solving sessions. In such a session, a teaching assistant will solve problems for the students; as a result, the students will often not be actively engaged in the solution process. In the PLTL group format used here, the students are all actively solving the problems and are assisting each other in the solution process. The study group facilitator acts to help keep the students on task, as well as provide hints if the group is unable to solve a problem on their own. Furthermore, the undergraduate student facilitators are often in a better position than teaching assistants to act as peer mentors to the students as the undergraduate facilitators are usually closer in age to the freshmen students in the PLTL groups. Finally, the cost of hiring undergraduate students on an hourly basis to lead the groups will usually be much less than the cost of hiring graduate student TAs to lead these important but fairly low-level mathematics study groups.

Semester	Freshmen	Total Participants (TP)		Participants – Attended 3 or more sessions		Participants – Attended 9 or more sessions	
	Number	Number	Percentage	Number	% of TP	Number	% of TP
Fall 2009	214	133	62.1%	100	75.2%	33	24.8%
Spring 2010	191	66	34.6%	29	43.9%	15	22.7%
Fall 2010	202	147	72.8%	145	98.6%	132	89.8%
Spring 2011	185	40	21.6%	40	100%	38	95%
Fall 2011	233	191	82.0%	190	99.5%	182	95.3%

Table 2: Cohort size and PLTL participation rates

2.3 PLTL Group Development and Implementation

At the institution under study, the PLTL groups were initially hastily created in the fall 2008 semester. As there was little advanced planning or preparation, they were sparsely attended and of little use. Specifically, there was minimal attendance at the one PLTL group made available to all engineering and computer science freshmen. The program was completely optional, and very few students took advantage of the opportunity. Significantly more planning was done so that the program grew considerably in the fall 2009 semester. For the fall 2009 semester, eight PLTL group facilitators were hired and trained, and all incoming freshmen were assigned to a PLTL group. The groups were specifically targeted towards a particular mathematics level: Math 105 (Intermediate Algebra), Math 116/117 (college Algebra/Trigonometry), and Math 231 (Calculus I). While two courses are covered by the Math 116/117 PLTL groups, many students in those groups are enrolled in both courses. This distribution of groups covered nearly all of the incoming engineering and computer science freshmen, as only a small percentage began their studies at a higher-level Calculus course (such as Calculus II) or at a lower-level mathematics course (such as Basic Algebra).

In the fall 2009 semester, as shown in Table 2, 133 students participated to some extent in the PLTL groups. However, as will be discussed below, many of these students attended less than half the sessions, as there was no requirement of attendance and no obvious penalty if they did not attend. Note, because the facilitators encourage all students to actively participate while in attendance, participation and attendance are considered synonymous here.

To encourage greater attendance, a specific course was created for the PLTL groups beginning in the fall 2010 semester. As seen in Table 2, there was greater overall attendance, and the vast majority of students who participated in the PLTL groups attended most of the weekly sessions (nine or more). The greater attendance is partially attributable to a grade being assigned to the specific course consisting of the PLTL group participation. This trend continued through the fall 2011 semester, with increased registration for the course achieved through stronger recommendations from academic advisers.

It may be noted that the PLTL groups are also conducted in the spring semesters. In the spring semesters, the PLTL groups for Math 105 are dropped, while PLTL groups for Math 232 (Calculus II) are added. As seen in Table 2, participation is significantly less in the spring semesters. While students would likely benefit from participation in formal PLTL groups in their second semester, anecdotal evidence suggests that many students have formed informal study groups as a substitute for formal PLTL groups by that time.

3. Study Methodology

To evaluate the effectiveness of the PLTL groups for aiding mathematics course performance, comparisons were made between the course grades of PLTL participants versus non-participants, as well as between students having different levels of attendance. Analysis focuses on the fall semesters, as the decreased participation in the spring semesters makes the number of students in many of the individual data categories very small. Some results from the spring semester are presented, but should be considered part of a trend rather than statistically significant on its own. Performance in the different courses is considered separately. First, we will consider the impact of the frequency of attending PLTL groups on student grades using data primarily from the fall 2009 semester. In this analysis, only the students who were members of the fall 2009 engineering and computer science incoming freshmen cohort are considered in this analysis of frequency of PLTL group participation. Second, using fall 2010 and fall 2011 data, we will compare the performance of a larger group of students who attended most of the PLTL groups (i.e., "frequent participants") in a given semester to that of students who did not participate in the groups. All students who took the courses in these semesters are included in the analysis.

Math 105 is a terminal mathematics course for many students at the institution, and therefore includes many students with poor mathematics aptitude. In the first analysis regarding the impact of the frequency of attending PLTL groups, an analysis of the impact of PLTL groups in Math 105 is made, but less emphasis is placed on this comparison because of the very large number of students from non-mathematics-oriented disciplines in the course. The presence of these students in the course tends to cause the overall course difficulty to be reduced, making it "easy" for many engineering and computer science students. As a result, it is naturally expected that engineering and computer science students will get high grades in the course even without participation in a PLTL group.

For the second analysis involving the impact of frequent participation in

PLTL groups on course grades, the focus is on Math 116 and 231, as these are courses which had more than 20 percent of the students in the course frequently participating in the PLTL groups; this provides for a meaningful comparison of performance between PLTL group participants and non-participants. In these semesters, 20-30 percent of the students in Math 116 and Math 231 participated in PLTL groups, with approximately 24 percent participated when the results from the fall 2010 and fall 2011 semesters are combined, while only approximately 12 percent of the Math 117 students were in PLTL groups. In addition, the focus of the PLTL groups that contain students from Math 116 and Math 117 is primarily on the material from Math 116. These factors make the analysis of the students in Math 117 less valuable, and so such an analysis is not included here. Math 105 is not considered in this analysis because (a) only a small fraction (approximately 1 percent) of the total number of students in the course were in PLTL groups, and (b) most of the students in Math 105 course are not in math-intensive disciplines. Therefore, the comparison between the groups of students (PLTL group participants vs. non-participants) is not appropriate.

4. Impact of the Frequency of PLTL Attendance

4.1 Results

Data from the fall 2009 semester are used to evaluate the impact of the number of weekly PLTL group sessions attended on student performance. A similar analysis for the spring 2010 semester was also performed, but the reduced number of participants limits the significance of this analysis. For this analysis, PLTL group attendance is divided into different categories: no attendance (0 sessions attended), minimal attendance (1-2 sessions), infrequent attendance (3-5 sessions), regular attendance (6-8 sessions), and frequent attendance (9-14 sessions). Grades were divided by range: "A" consists of all A and A- grades, "B" consists of all B+, B, and B- grades, "C" and "D" are similar to the "B" designation, and "F/WD" contains all grades of F and mid-semester withdrawals from the course. These distributions were used to avoid having the data distributed into groups too small for reasonable analysis.

Figures 1-4 show the grade distributions for the fall 2009 semester from students in the PLTL groups for Math 105, Math 116, Math 117, and Math 231. Note, the incoming freshmen students in Math 231 tend to be among the best prepared in the college, while students in Math 105 are often among the worst prepared. Nonetheless, nearly all of the engineering and computer science students in Math 105 have had the course material during their studies in high school and often find Math 105 rather redundant and uninteresting.

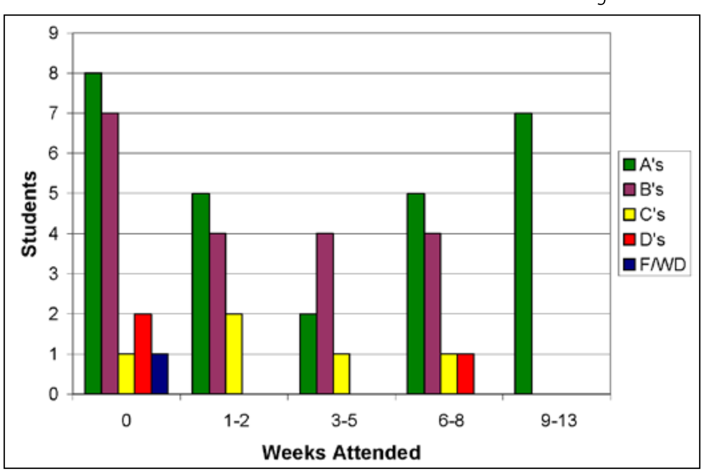

Figure 1: General grade distribution for freshmen engineering and computer science students (n=55) in Math 105 during the fall 2009 semester. The students are grouped by the number of weekly PLTL group sessions attended.

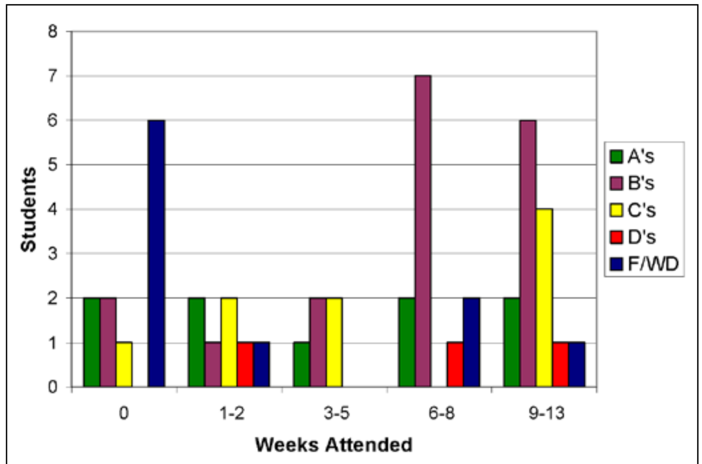

Figure 2: General grade distribution for freshmen engineering and computer science students (n=49) in Math 116 during the fall 2009 semester. The students are grouped by the number of weekly PLTL group sessions attended.

First considering Math 105, in Figure 1, it can be seen that there were a substantial number of students who did not need PLTL groups to succeed in the course. But beyond those students, there is a trend of improved performance as PLTL group attendance increased. The trends for enhanced performance with increased PLTL group performance are more evident in Math 116 and Math 117 (Figures 2 and 3). Math 116 is a course which tends to give many

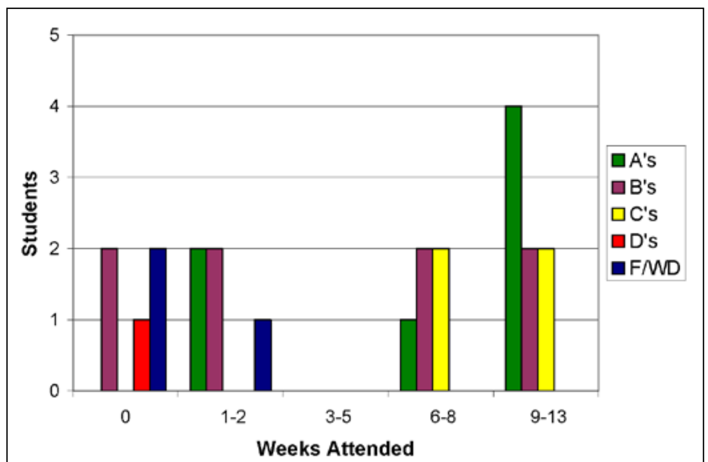

Figure 3: General grade distribution for freshmen engineering and computer science students (n=23) in Math 117 during the fall 2009 semester. The students are grouped by the number of weekly PLTL group sessions attended.

students at the institution trouble, as evidenced by an overall course GPA of 1.84/4.0 (indicating that the average course grade is between a "C" and "C-") by all students taking the course during the fall 2009 semester. As can be seen, the student grades in Math 116 were clearly higher for students attending many PLTL groups, while most of the grades of F/WD were earned by students who attended no PLTL groups. Similarly, the majority of grades in the A and B ranges in Math 117 were earned by students who attended six or more of the PLTL group sessions (the "regular" and "frequent" attendees). The results from Math 231 (Figure 4) are less clear. Again, there appears to be a group of students who succeed without formal PLTL groups. Beyond that, there is a trend of increasing frequency of grades in the A range with increased PLTL group attendance, an increase and then decrease in B grades, but also a persis-

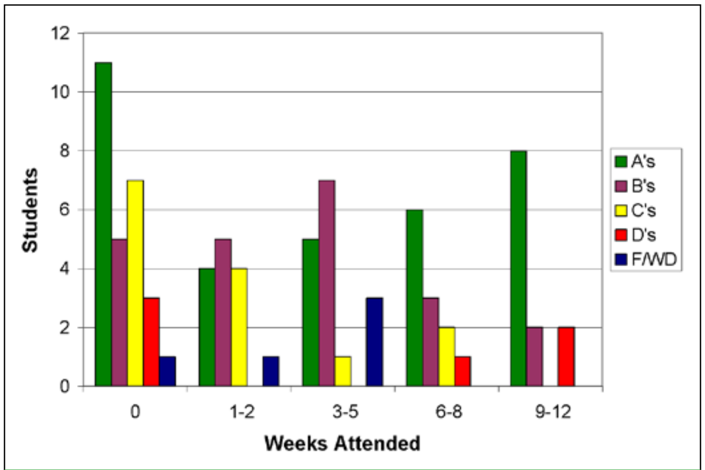

Figure 4: General grade distribution for freshmen engineering and computer science students (n=81) in Math 231 during the fall 2009 semester. The students are grouped by the number of weekly PLTL group sessions attended.

tence of poor grades, albeit at a much lower frequency than the good grades. However, the shift in grades from the B and C ranges to A-range grades with increased attendance is a trend supporting the value in frequent attendance at the PLTL groups.

As mentioned, the analysis of the data from the spring 2010 semester is complicated by the decrease in the number of students who attended the PLTL groups. The number of students in any particular course who participated frequently in the PLTL groups declined to four to six in each course. However, it can be noted that for all four courses in the spring 2010 semester, nearly all of the grades in the D or F ranges came from students who did not attend or who minimally attended PLTL groups. Twenty-five students who attended two or fewer PLTL group sessions received grades in the D and F ranges, while only four students who attended three or more PLTL group sessions received such grades. This suggests that either the PLTL groups do help or that the weaker students were not aware of their own deficiencies. Considering that most of the poor grades were in Math 116 and Math 117, the students receiving these grades had generally taken Math 105 in their first semester and the Math 105 students saw the least need for the PLTL groups in the fall 2009 semester, this latter scenario is very plausible. Overall, while the data support the trends seen in the fall 2009 semester indicating the benefit of greater participation in the PLTL groups, by itself the data are too sparse to generate conclusions.

4.2 Discussion

One item that should be noted is that there is no obvious correlation between the frequency of attendance of the PLTL groups and the students' pre-existing mathematics abilities as evaluated by their Math ACT (a college entrance exam) score. In fact, the only trend that can be noted while trying to correlate these is that students with higher Math ACT scores were slightly inclined to attend the PLTL groups less frequently. So the increased level of participation by some students should not be attributed to these students being overall better academic performers.

The analysis of the data from the fall 2009 PLTL group participation results in two primary observations. First, there is a group of students who will perform well in a class without a formal PLTL group. This is not surprising as there have always been students who have received good grades in courses without the assistance of a formal PLTL group or similar intervention. The difficulty arises in attempting to determine if a particular student will fit into this category of students or will be a student who is better served through participating in an intervention such as a PLTL group. For example, one can not rely on a student's self-assessment of their own abilities. Students in Math 105 often see little reason for participating in the PLTL group and can succeed in Math 105 without that assistance. However, these same students then subsequently struggle to succeed in Math 116 and Math 117 while receiving no assistance. And while there is a slight correlation between students with higher ACT scores and reduced participation in PLTL groups, it is not a compelling correlation with regards to student success without participating in PLTL groups.

The second observation is that there is a clear trend towards higher grades among students who participate in PLTL groups at a regular or frequent level. This does not mean that every student who participates weekly in a PLTL group will receive a high grade in the course; rather, students who participate regularly or frequently in the PLTL groups receive grades in the A and B ranges more frequently than students who participate at lesser levels. From the limited data available from this one semester, it is reasonable to conclude that increased PLTL participation is beneficial to the students.

A third, but lesser, observation is that there is no evidence that PLTL group participation is detrimental to students. So, while any particular student may not benefit as much as other students through the PLTL groups, there is no reason to think that the groups hinder student progress.

5. Impact of Substantial PLTL Group Participation

5.1 Results

Data from the fall 2010 and fall 2011 semesters are used for comparison between PLTL group participants and non-participants in the courses. As discussed and shown in Table 2, there was a much greater percentage of participants attending the PLTL groups frequently (nine or more times) beginning in the fall 2010 semester. As 89 percent or more of the students in those semesters who participated in a PLTL group are classified as frequent attendees, the data from all participants are combined and compared to the course performance of students who did not attend the PLTL groups. As a very large percentage of students attended most of the PLTL group sessions, the impact of the number of study groups by a particular student will be insignificant in this analysis.

While nearly all of the students in Math 116 and Math 231 are in math-intensive disciplines (primarily STEM disciplines in the physical sciences and mathematics as well as some disciplines such as economics), it is important to have a baseline comparison between the performances of first semester engineering freshmen and the rest of the students in the courses. To do this, we consider the fall 2007 semester, which was before any of the PLTL group interventions were introduced. In the fall 2007 semester, 65 freshmen engineering and computer science students took Math 116, and 74 took Math 231. For Math 116, engineering and computer science freshmen received a higher average grade (2.49 vs. 2.21 out of 4.0) than the other students in the course, with an independent-samples t-test p-value of 0.15 between the two groups. For Math 231, engineering freshmen received an average grade that was 0.20 points higher than others in the course, with an independent-samples t-test p-value of 0.24 between the two groups. These results suggest that engineering freshmen students perform slightly better than the other students in the courses, but not at a strongly statistically-significant level. With this baseline, it can be determined whether PLTL groups boost the performance of frequent participants.

Figures 5 and 6 present the distribution of course grades between PLTL group participants and non-participants for Math 116 and Math 231 for the fall 2010 semester, and Figures 7 and 8 present these distributions for the fall 2011 semester. The results are given in terms of percentages of students in each category with each grade, so as to not distort the figures through the differences in the sample sizes of the two populations. Table 3 provides a statistical summary of the performance in the participants and non-participants

		Math 231 Calculus I		Math 116 College Algebra	
		PLTL	No PLTL	PLTL	No PLTL
Fall 2010	Average Grade	2.49	2.06	2.38	2.02
	Std. Dev.	1.28	1.44	1.15	1.26
	Students	59	281	43	213
	ANOVA p-value	0.034		0.084	
Fall 2011	Average Grade	2.63	2.04	1.84	1.71
	Std. Dev.	1.26	1.34	1.39	1.31
	Students	74	268	53	190
	ANOVA p-value	0.001		0.528	
Combined	Average Grade	2.57	2.05	2.08	1.87
	Std. Dev.	1.27	1.39	1.31	1.29
	Students	133	549	96	403
	ANOVA p-value	0.000		0.153	

Table 3: Average course grades and statistical analysis for cohorts of students who participated in (PLTL) and did not participate in (No PLTL) the PLTL groups in Math 231 and Math 116 for the fall 2010 and fall 2011 semesters. The combined results from the two semesters are also included.

for these two courses in the fall 2010 and fall 2011 semesters, as well as a combination of the two semesters.

As can be seen in Figures 5-8 and Table 3, the participants in the PLTL groups tended to do better than the non-participants in Math 231 (Calculus I) to a high degree of statistical significance. While the PLTL group participants still did better than the non-participants in Math 116 (College Algebra), the difference was smaller than in Math 231. When compared to the baseline data when no PLTL groups were used, the impact of the PLTL groups on the grades of participants in Math 116 was minimal as the baseline data comparison and the PLTL groups comparison had similar p-values statistically.

Because the format of the PLTL group program was so similar between the fall 2010 and fall 2011 semesters, the data from those semesters can be combined to give larger populations for study. It should be noted that there is still value in considering semester-by-semester results as other factors

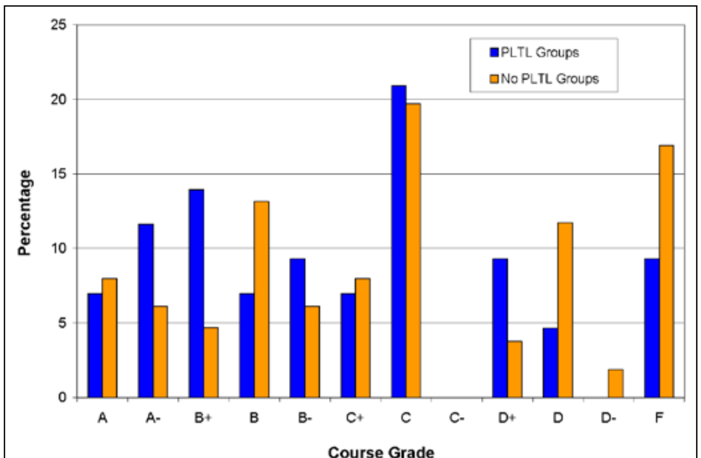

Figure 5: Percentage of each course grade earned by students who participated in the PLTL groups and those who did not participate in the PLTL groups for Math 116 in the fall 2010 semester.

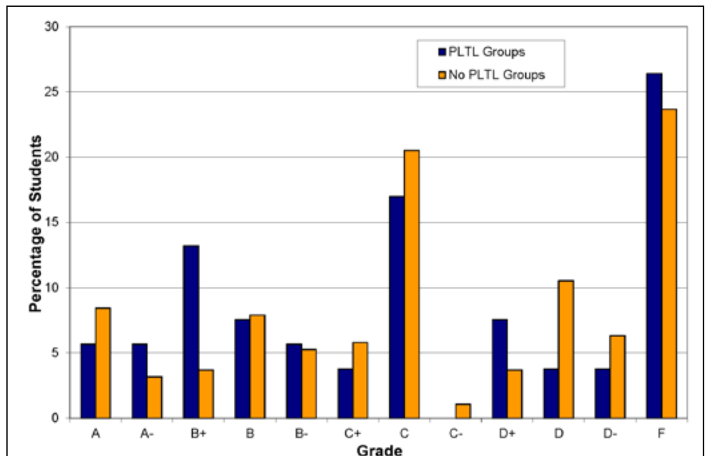

Figure 7: Percentage of each course grade earned by students who participated in the PLTL groups and those who did not participate in the PLTL groups for Math 116 in the fall 2011 semester.

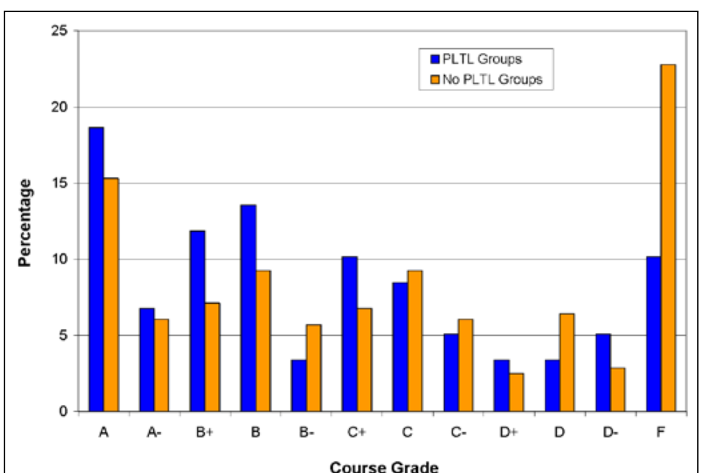

Figure 6: Percentage of each course grade earned by students who participated in the PLTL groups and those who did not participate in the PLTL groups for Math 231 in the fall 2010 semester.

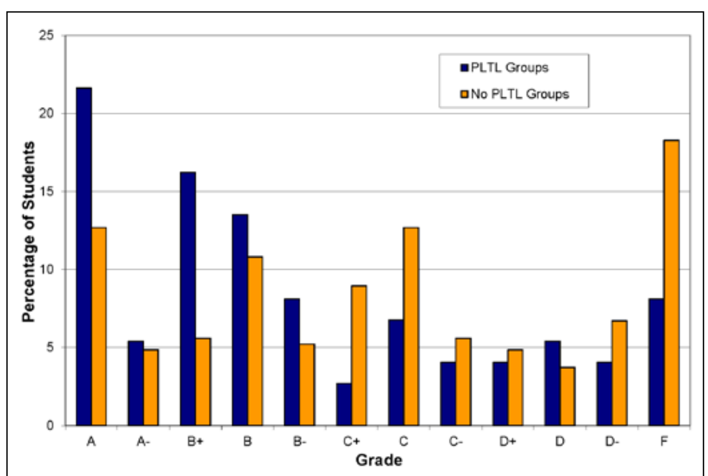

Figure 8: Percentage of each course grade earned by students who participated in the PLTL groups and those who did not participate in the PLTL groups for Math 231 in the fall 2011 semester.

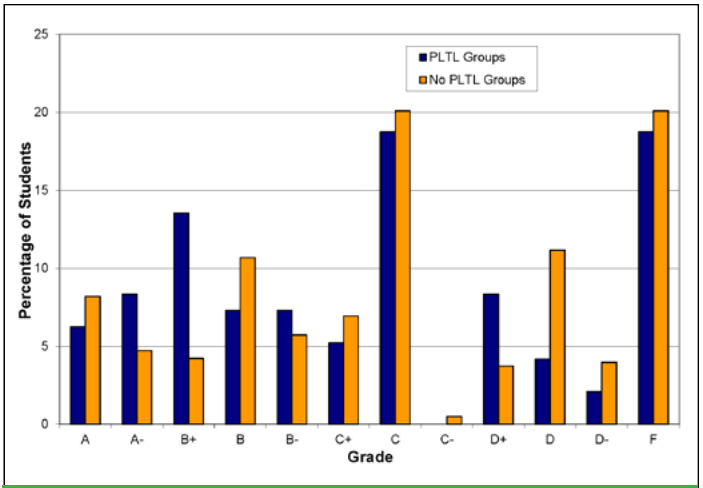

Figure 9: Percentage of each course grade earned by students who participated in the PLTL groups and those who did not participate in the PLTL groups for Math 116 in the combined fall 2010 and fall 2011 semesters. It can be noted that 66.7 percent of the students in the PLTL groups received grades of C or better, while 60.5 percent of the students not in the PLTL groups received such grades.

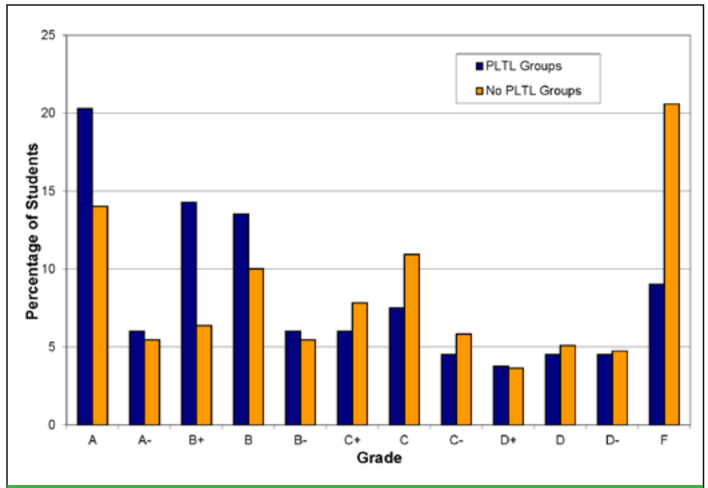

Figure 10: Percentage of each course grade earned by students who participated in the PLTL groups and those who did not participate in the PLTL groups for Math 231 in the combined fall 2010 and fall 2011 semesters. It can be noted that 73.7 percent of the students in the PLTL groups received grades of C or better, while 60.1 percent of the students not in the PLTL groups received such grades.

that may influence student learning, such as course instructor changes, are then captured in the results. But the combined results, as shown in Table 3, also provide value by giving an overview of the impact of the program over multiple years. Figures 9 and 10 provide the percentage grade distributions for the two courses between the participants and the non-participants. The combined results further show that the PLTL groups improve student performance in Math 231, while having only a small impact in Math 116.

A summary of the results for the spring 2011 semester for Math 231 and Math 232 is provided in Table 4. Note, the populations of the students who participated in PLTL groups are greatly reduced for the spring 2011 semester, but participants experienced dramatically higher average grades than non-participants. However, with the small number of participants, it is possible that there may be some self-selection for using the PLTL groups by more dedicated students. Conversely, the PLTL group participants in the spring 2011 semester may be primarily students who most recognized the value of PLTL groups in assisting their learning of the course material.

5.2 Discussion

As discussed, the large percentage of students in PLTL groups who were frequent participants in the fall 2010 and fall 2011 semesters allows for valid comparisons between all participants and all non-participants in the PLTL groups. The data from the participants are grouped together as nearly all students who participated in PLTL groups did so at a frequent level, thereby negating the impact of the frequency of attendance on the results. The results can be considered with respect to the slightly higher average grades earned by the freshmen engineering students in the fall 2007 semester.

The data in Table 3 and in Figures 6, 8, and 10 indicate that the participants in the PLTL groups in Math 231 (Calculus I) perform much better in the course than the non-participants. Even when the fall 2007 baseline results for the first-semester engineering students are considered, the performance of the PLTL group participants exceeds that of the non-participants by a statistically-significant amount.

Comparison of the grade distribution in Math 231 indicates a consistent trend of participants getting grades in the A and B range at a higher percentage, while non-participants get grades of C or below, and particularly grades of F, at a much higher rate. This does not necessarily mean that participating in a PLTL group is changing grades of F into grades of A, but is more likely an indication that the grades are being gradually shifted, so that grades of C are becoming Bs, Ds are becoming Cs, and Fs are becoming Ds or Cs. The result of such a shift is that there will be fewer grades of D and F and more grades of A and B for participants, while grades will stay lower for non-participants.

The trends in improvement for Math 116 are not as strong, and appear minimal in light of the fall 2007 semester baseline grade comparison. Table 3 does show that participants in the PLTL groups do get better grades on average, but the trend is more towards a 0.2 increase in a grade, rather than the 0.5 increase in a grade seen in Math 231. This 0.2 higher average grade is very comparable to what was achieved by the fall 2007 first-semester engineering and computer science freshmen without PLTL groups. This suggests that the PLTL groups are having a minimal impact on the Pre-Calculus course performance of the freshmen engineering and computer science students. The course grade distributions shown in Figures 5, 7 and 9 confirm this. Unlike

	Math 232		Math 231	
	PLTL Groups	No PLTL Groups	PLTL Groups	No PLTL Groups
Average Course Grade	2.65	1.99	2.80	2.37
Std. Dev.	1.15	1.24	1.26	1.34
Students	20	233	15	266
ANOVA p-value	0.022		0.226	

Table 4: Average Course Grades and Statistical Analysis for Students Who Participated in and Did Not Participate in PLTL Groups in the spring 2011 Semester

the fairly dramatic differences seen for Math 231, the distributions between participants and non-participants are not as obvious. There is some increase in the number of grades of B- or higher, and some decrease in the low grades for participants, but the shift is not as substantial as in Math 231.

As shown in Table 4, the limited results for Math 232 PLTL groups indicate that they are successful for students participating in those groups. However, the number of students involved is small and may be more greatly influenced by student quality in self-selecting to participate in the PLTL groups rather than by true benefits provided by the groups.

Overall, the impact of the PLTL groups on student success in Math 231 is similar to what has been seen in other studies concentrating primarily on other STEM disciplines. The amount of course grade improvement is on par with the other studies (Gosser, 2011, Liou-Mark et al, 2010). Furthermore, as previously reported by Loui, et al. (2009), the PLTL groups do not always succeed; some cohorts of students in some semesters do not see gains in their course performance. This is what was seen particularly in the fall 2011 data for Math 116. In general the PLTL groups aid student performance, but the use of such groups is no guarantee of success for all students. Broader studies of the effectiveness of PLTL groups are needed to determine what types of students will most benefit from PLTL group participation.

The results seen in this study naturally lead to a question as to why PLTL groups appear to be beneficial for freshmen engineering students in a Calculus course, but not in a Pre-Calculus course. A definitive answer to this may require analysis of several more semesters of student performance, but there are observations that can be made at this point. In Math 116, the higher grades earned by PLTL group participants was much more significant in the fall 2010 semester versus the fall 2011 semester. Future semesters can clarify which semester is unusual, and may help determine if there was a problem in the fall 2011 semester with study group facilitators or course instructors in Math 116.

Another issue to consider is that most of the engineering freshmen have had the material covered in Math 116 previously in their secondary school educations. However, most of the students would have been taught relatively little of the Calculus material covered in Math 231. As students in Math 231 are learning much of the material for the first time, they may approach the PLTL groups in a more open-minded fashion, and be more receptive to the learning tools and additional work that they are gaining in the groups. Whereas, if students in Math 116 believe that they already know much of the material, they may be less interested in devoting effort to incorporating PLTL group activities into their studies and achieve less benefit from the groups. As mentioned previously, facilitators in Math 105 PLTL groups have frequently encountered this attitude. Engineering freshmen in Math 105 often believe that they fully understand the course material, and therefore many are not as receptive to the learning techniques being stressed in the PLTL groups. While this attitude is not as widespread among Math 116 students, it is logical that it is present to some degree in the Math 116 students who have had the course material in their secondary school education.

6. Conclusions

After studying the impact of PLTL group participation on the performance of freshmen engineering and computer science students in their foundational mathematics courses, several conclusions can be drawn. First, the PLTL group participation often has a positive impact on student grades in the courses, although there are some students who can excel in their first college mathematics classes without the use of PLTL groups. Second, students who participate more frequently in the PLTL groups see greater success in their mathematics courses, with larger percentages of higher grades being achieved by students with frequent participation, and larger percentages of lower grades being achieved by students with little participation.

Third, the PLTL groups appear to be much more beneficial to students in Calculus courses as opposed to Pre-Calculus courses. This does not mean that the PLTL groups are not helpful to students in Pre-Calculus courses, but that the course grade improvement is greater for students in Calculus courses. The impact of the PLTL groups on the student performance in Pre-Calculus courses is minimal in comparison to the performance difference seen when no PLTL groups were offered.

Overall, the PLTL group model, when applied to students who participate fully, is an effective strategy for improving the performance of freshmen engineering and computer science students in foundational mathematics courses, particularly at the Calculus level. The use of PLTL groups will not benefit all students, but is an effective educational supplement to the typical lecture format used in the mathematics courses considered here for many students. While the ultimate goal of improving graduation rates remains to be studied, the use of PLTL groups does help students begin their college studies in a positive fashion.

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