120th ASEE Annual Conference & Exposition
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June 23-26, 2013
ATLANTA

Paper ID #5685

A Study of the Impact of Peer-Led Team Learning on the First-Year Math Course Performance of Engineering Students

Dr. John R. Reisel, University of Wisconsin, Milwaukee

Dr. John R. Reisel is an associate professor of Mechanical Engineering at the University of Wisconsin-Milwaukee (UWM). He serves as associate director of the Center for Alternative Fuels, and co-director of the Energy Conversion Efficiency Lab. In addition to research into engineering education, his research efforts focus on combustion and energy utilization. Dr. Reisel was a 2005 recipient of the UWM Distinguished Undergraduate Teaching Award, a 2000 recipient of the UWM College of Engineering and Applied Science Outstanding Teaching Award, and a 1998 recipient of the SAE Ralph R. Teetor Educational Award. Dr. Reisel is a member of ASEE, ASME, the Combustion Institute, and SAE. Dr. Reisel received his B.M.E. degree from Villanova University in 1989, his M.S. degree in mechanical engineering from Purdue University in 1991, and his Ph.D. in mechanical engineering from Purdue University in 1994.

Ms. Marissa Jablonski, University of Wisconsin, Milwaukee

Marissa R. Jablonski is a Ph.D. student of Civil/Environmental Engineering at the University of Wisconsin-Milwaukee (UWM). She serves as program coordinator of the National Science Foundation (NSF) funded FORTE (Fostering Opportunities for Tomorrow's Engineers) program at UWM. Jablonski is focusing her dissertation on sustainable oxidation of textile waste water and is working to create small-scale waste water treatment units for cottage textile industries. She trained at the National Environmental Engineering Research Institute (NEERI) in Nagpur, India where she worked on bio-degradation of azo dye intermediates. Jablonski served as co-chair of UWM's student chapter of Engineers Without Borders for two years after its inception in 2007. She continues to help design and implement water distribution projects in Guatemala. Jablonski was a 2012 recipient of NSF's EAPSI fellowship in China; a 2008 recipient of the NSF Graduate Fellowship Honorable Mention; the 2008 recipient of the Wisconsin Water Association Scholarship; and the 2007, 2008, 2009, 2010, and 2011 recipient of the UWM Chancellor's Graduate Student Awards. Jablonski is a member of ASEE, EWB, SWE, and ASCE. She received her B.S. degree in Natural Resources and Spanish from the University of Wisconsin-Stevens Point in 2003 and her M.S. degree in Civil/Environmental Engineering from UWM in 2009. She will receive her Ph.D. in Civil/Environmental Engineering from UWM in 2013.

Ethan Munson, University of Wisconsin, Milwaukee

A STUDY OF THE IMPACT OF PEER-LED TEAM LEARNING ON THE FIRST-YEAR MATH COURSE PERFORMANCE OF ENGINEERING STUDENTS

Abstract

As part of an NSF-sponsored STEP grant, formal peer-led team learning (PLTL) groups were created for first-year engineering and computer science students. The groups were organized around the math course taken by the students so that all students in a particular group were taking the same math course. In both the 2010-11 and 2011-12 academic years, these groups were offered as a formal class, with students receiving a grade based upon participation. This was done to stress the importance of the groups to the students, and increase the level of participation by the students. Work with the groups in previous years showed that increased levels of participation led to greater impacts on student grades.

Approximately 73% of the first-year students in engineering and computer science participated in these PLTL groups in 2010-11, with most students attending most of the weekly sessions. This participation rate increased to 82% in 2011-12. The impact of the PLTL groups on students in Calculus-level classes (Calculus I and II) was strong. When compared to all students in the Calculus courses who did not participate in the PLTL groups, the grades of the students who participated in the PLTL groups were generally 0.4-0.7 points (on a 4-point scale) higher. However, the results at the Pre-Calculus level (College Algebra and Trigonometry) were not as impressive. Students in the PLTL groups in College Algebra only had average grades 0.2 points higher than non-participants, while the Trigonometry students demonstrated little impact from the PLTL groups. This difference may be a result of the students' self-perceived need for the PLTL groups, with Calculus-level students seeing a greater need for the groups.

In this paper, the format of the PLTL groups is described in detail, and a detailed analysis of the impact of the PLTL groups on the student grades is presented.

Introduction

In the United States today, there is great interest in increasing the number of students graduating from college in the Science, Technology, Engineering, and Mathematics (STEM) disciplines.[1,2] For this goal to be achieved, there are two primary tasks that need to be accomplished. First, more students must be recruited to pursue college-level studies in the STEM fields. Second, once those students are enrolled in STEM fields, the colleges and universities need to provide a nurturing environment designed to allow a wide range of students to succeed, while at the same time providing a rigorous education.

The College of Engineering and Applied Science (CEAS) at the University of Wisconsin-Milwaukee (UWM) has generally been able to attract as many students into its engineering and computer science programs as for whom it can provide quality educations. But the graduation rates have been lower than desired. For example, the college's 6-year graduation rate for Fall 2005 incoming freshmen was 24.3%. Recognizing that this graduation rate is undesirably low in that it indicates that most incoming freshmen students in CEAS are not achieving their ultimate goal of graduation in STEM fields, CEAS has sought to improve student success through several activities. One of these activities is the creation of peer-led team-learning (PLTL) groups for incoming freshman, with these groups being led by an upper-level undergraduate student who also serves as a peer mentor. The use of peer mentors and PLTL groups is not a new concept, and has been shown to be successful elsewhere.[3-5] As math courses tend to be one of the most difficult hurdles for incoming students in CEAS to overcome, the PLTL groups focus on the appropriate math courses.

The PLTL groups were created as part of an NSF-funded STEM Talent Expansion Program (STEP) grant. First-year students in engineering and computer science register for small PLTL groups based upon their math course. The groups meet once a week in one-hour sessions to assist students in mastering their math coursework. An additional goal of the groups is to create an open environment where peers can discuss engineering and computer science interests and applications. The widespread use of the groups is now in its fourth year at UWM. In 2008-09, a pilot program was offered that was completely optional and voluntary for the students. Participation in the program was very poor, so in 2009-10, incoming students were assigned to specific PLTL groups. While attendance improved, scheduling difficulties and a desire to increase attendance even further led to the college formally creating a course designation for the PLTL groups beginning in the Fall 2010 semester. Students are strongly encouraged to enroll in the PLTL groups by their academic advisors. This has led to strong participation in the PLTL groups in the Fall semesters, although participation decreases in the Spring semesters.

In this paper, "participation" in a study group will be defined as participating in at least one weekly study group session during a given semester. Furthermore, the degree of participation will be distinguished by the weekly attendance. The degree of participation was particularly relevant in Fall 2009/Spring 2010 when the variation in attendance by students was quite high. Beginning in the Fall 2010 semester, nearly all of the students who participated in the PLTL groups attended 9 or more of the weekly sessions, of which there were 13 or 14 per semester. Such degree of participation is classified as strong participation. Previous work found that this level of participation was adequate for noticeable impact on student grades.[6] Students who participated in no PLTL groups in a semester are considered in the category of "Did Not Participate".

Format and Purpose of the PLTL groups

In the PLTL groups, students work together to solve appropriate math problems with the guidance and some tutoring provided by peer mentors; these peer mentors are upper-level undergraduate students in the college. PLTL groups aim to develop student confidence in collaborative problem solving skills and teach students during their first year in college how to practice independent problem solving methods. This procedure requires deep thought, time, discussion and risk taking; these are all skills beneficial for careers in engineering and computer science. For this reason, peer mentors do not have solution manuals. The peer mentors act as facilitators who work with students to solve problems methodically while encouraging critical thinking, as opposed to supplying answers to questions. Ideally, learning problem solving skills in a group raises the confidence levels of the students early in their college career. These skills then should transfer to their independent work. The use of PLTL groups is expected to increase retention and graduation and decrease such detrimental practices as cheating.

In the Fall semesters, PLTL groups are organized around Intermediate Algebra (Math 105), the PreCalculus courses of College Algebra (Math 116) and Trigonometry (Math 117), and Calculus I (Math 231). In the Spring semester, the PLTL groups for Math 105 are dropped, and groups are added for Calculus II (Math 232).

Mentor Preparation

The student peer mentors were hired and trained according to two *Peer-Led Team Learning* books: *A Guidebook,*[7] and *A Handbook for Team Leaders*.[8] Their hiring and training was done by Prof. Ethan Munson of the Electrical Engineering and Computer Science Department, who served as the faculty member responsible for this program, and Ms. Marissa Jablonski, a Ph.D. student who serves as program coordinator responsible for many day-to-day activities. Mentors are taught that peer-led learning can be more effective than the traditional lecture format of college courses. Mentors were hired based on willingness to help, openness to the lecture-free format of the PLTL groups, and success of having earned an average grade of 2.7 or higher in their own College Algebra, Trigonometry, and Calculus classes. The main duty of the peer mentors is to keep students working toward a solution to the problem under consideration and to keep them focused during discussions. Mentors are taught to think of themselves as a coach or role model rather than a teacher and to instill the idea that hard work will help the students succeed in their math courses. This is further reinforced in the students because the mentor's presence alone demonstrates success in the college is possible. As role models, mentors are expected to represent the school and are not to be spreading rumors or talking poorly of professors, classes, or the college. Since peer mentors are in direct contact with students, mentors can be the difference between success and failure of the students as they enter the college. They are in a position to inspire students and are encouraged to engage students in discussions about engineering career paths, design projects, or current events. As another part of training, mentors are also given advice on how to handle different personalities and learning styles and there is a discussion about how different learning styles may be the cause of misunderstandings and frustration. Mentors are given a list of sample questions and ice breaking statements that come from the *Peer-Led Team Learning* books.[7,8]

Mentors are required to prepare at least one hour per week for their groups. Mentors are assigned two or three PLTL groups and are given the syllabus of the courses for which they will be peer mentors. Copies of the College Algebra, Trigonometry, and Calculus textbooks are available for use by the mentors in a central location which is accessible to the mentors at all times. This enables mentors to prepare for their groups and to identify any areas which they perceive may be trouble areas for the students. Mentors are encouraged to work out some problems to be sure that they understand the topics to be covered. All mentors 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 the mentors to share with each other the progress of their groups and to give each other encouragement and advice. As an example of the interaction that occurs at these meetings, at one meeting the mentors mentioned that students in Intermediate Algebra felt that the material was too easy to justify a study group. The program coordinator suggested creating worksheets to change the format of the material in order to keep students on task. One mentor then created a worksheet and brought feedback to the other mentors responding that it was well worth her time. Creating a five question worksheet proved to be easy preparation for her and created a challenging objective for the group. The results showed the students in her group their weaknesses in a format different from the in-class tests and verified that they did indeed need to study and that attendance in the study group is worthwhile.

PLTL Group Logistics

As described elsewhere[6], students arrive at PLTL groups to find that the mentor has organized the seating in the room to be in a U-shape with all chairs and desks facing the white board. The mentor takes a seat as if s/he is a part of the group. The mentor facilitates collaborative group work by opening communication and asking about problem areas from the lecture or homework. Once a problem is stated, the mentor will open up the discussion of the solution to the whole group. Students begin to work on the problem which is often chosen from their assigned homework problems. In the beginning, students may need assistance finding procedures to solve problems in the textbook, at which point mentors will use some tutoring skills. As the semester progresses and the students gain experience, students will decrease their reliance on mentors to facilitate and will be able to function as a working study group on their own.

Note that this format differs from that of a common alternative format of TA-led problem-solving sessions. In such a session, a teaching assistant will solve problems for the students, who will be actively engaged in the process to varying degrees. In the study group format used here, the students are all actively solving the problems, and are assisting each other in the solution process. The study group mentor acts as a facilitator 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, as the mentors are closer in age to many of the students in the PLTL groups than graduate teaching assistants would typically be, the student mentors can act as peer mentors more effectively than graduate TAs. Finally, the cost of hiring undergraduate students on an hourly basis to lead the groups is typically much less than the cost of hiring graduate TAs to lead these important but fairly low-level math PLTL groups.

PLTL Group Evolution

The evolution of the format of the PLTL group program is discussed in more depth elsewhere.[9] Currently, CEAS incorporates the PLTL groups into a formal program of study as a one-credit Introduction to Engineering course placed into the schedule of classes. Advisors strongly recommend that all incoming college freshmen register for the course. In the Fall semesters, approximately eighteen fifty-minute sections are available. These are offered, typically, on Mondays, Tuesdays, and Wednesdays at three different times, such as 9:00-9:50 am, 1:00-1:50 pm, and 6:30-7:20 pm. The sections were designed to concentrate on specific math courses, and students register for the appropriate section based on their math course. A mix of new mentors and returning mentors from the previous year is used. The returning mentors are able to share their experiences and serve as role models for the new mentors. Most incoming freshmen register for the course and the vast majority attends throughout the semester. Having the class as a part of their weekly schedule, coupled with introducing a grade for the course based upon active participation, has increased attendance. Nearly all students who participated in the PLTL groups attended more than 2/3 of the meetings.

While participation is strong in the Fall semesters, it does drop in the Spring semesters. For example, whereas 147 students (73%) participated in the Fall 2010 semester, only 40 participated (22%) in the Spring 2011 semester. Again, in the Fall 2011 semester 191 students (82%) participated, but this only dropped to 96 (~45%) in the Spring 2012 semester. A likely cause of this increase in the Spring 2012 semester is that the college advising office began to require students who started in classes below Calculus I in the Fall 2011 semester to register for the PLTL groups in the Spring 2012 semester. While the Spring semester participation is still below what is desired, the participation rate in the Spring 2012 semester was reasonable.

Results and Discussion

Starting in the Fall 2010 semester, nearly all students (i.e., 90% in the Fall 2011 semester, 95% in the Spring 2012 semester) who participated in the PLTL groups attended nine or more of the weekly sessions, which is a level that corresponds to an attendance rate of over 64%; while anything less than perfect attendance is not ideal, this level of participation was grouped previously in our top level of participation and was found to noticeably improve course grades.[6] Due to the large number of students who participated in the PLTL groups in the Fall 2010 and Fall 2011 semesters, and the high level of attendance, this analysis focuses on comparisons between the students who participated at all levels in the PLTL groups and the remainder of the students in the course. Furthermore, this analysis will concentrate on Math 116 and Math 231. PLTL groups are also used for CEAS students in Intermediate Algebra (Math 105), but Math 105 is not considered in this analysis. Math 105 is a terminal math course for most students at the university and primarily contains students who have little interest in or use for math in their studies. As a result, when comparing the non-engineering students to engineering students (who likely have a higher interest in math as well as more incentive to do well in the course), there are clearly going to be other factors involved in the analysis which will mask the impact of PLTL groups.

In addition, students in Math 117 (Trigonometry) also use PLTL groups, but it too is not included in the analysis due to a lower rate of study group participation by students in this class. In the Fall semesters considered, ~24% of the students in Math 116 and Math 231 participated in PLTL groups, while only ~12% of the Math 117 students were in PLTL groups. In addition, the focus of the PLTL groups that contain students from both 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 a detailed analysis is not included here.

Math 116 and Math 231 all are taken by students who are in math-intensive disciplines, and in particular nearly all of the students in these courses are in a STEM discipline. Therefore, when one compares students who participated in a PLTL group versus students who were not in the formal PLTL groups, one is comparing students of similar backgrounds, needs, and aptitude for Math 116 and 231. The students who did not participate in PLTL groups for these courses usually fall into the following categories: (1) CEAS freshmen who chose not to participate in the PLTL groups, (2) freshmen in other, primarily STEM, majors, and (3) non-freshmen who either were repeating the course or who had taken lower-level courses in previous semesters and had advanced into these courses.

While nearly all of the students in Math 116 and Math 231 are in math-intensive disciplines, it is important to have a baseline comparison between the performances of first semester CEAS 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. For Math 116, engineering freshmen received a higher average grade (2.49 vs. 2.21 out of 4.0) than the other students in the course, with an ANOVA 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 ANOVA p-value of 0.24 between the two groups. These results suggest that engineering freshmen students perform slightly better than the other students in these courses, but not at a highly statistically-significant level. With this baseline, it can be determined whether PLTL groups boost the performance of frequent participants.

Figures 1 and 2 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 3 and 4 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 1 provides a statistical summary of the performance in the participants and non-participants for these two courses in the Fall 2010 and Fall 2011 semesters, as well as a combination of the two semesters.

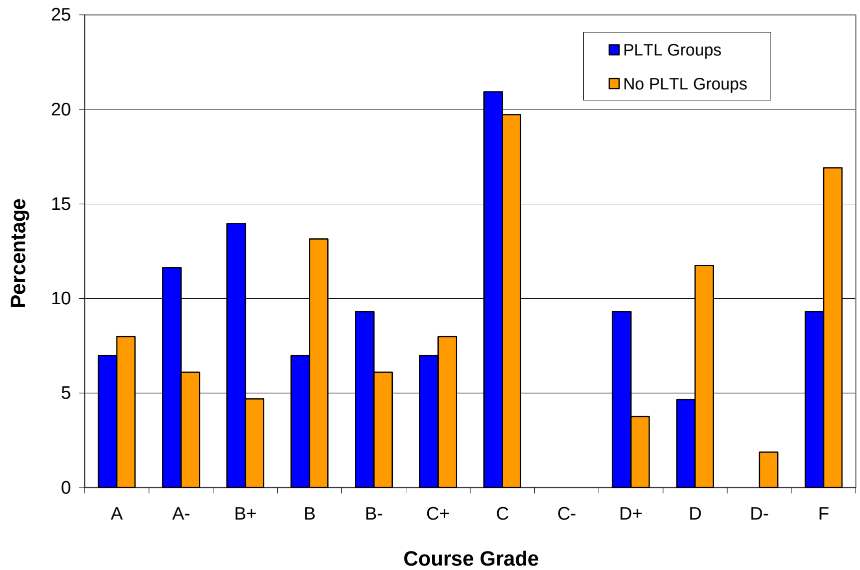

Figure 1: Percentage of each course grade earned by students who participated in the PLTL groups and those who did not participate in the PLTL groups for Math 116 in the Fall 2010 semester.

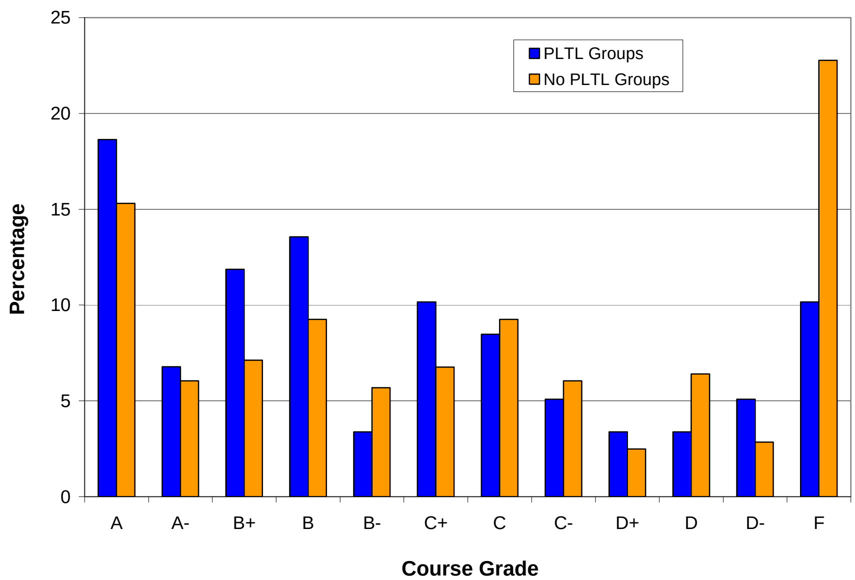

Figure 2: Percentage of each course grade earned by students who participated in the PLTL groups and those who did not participate in the PLTL groups for Math 231 in the Fall 2010 semester.

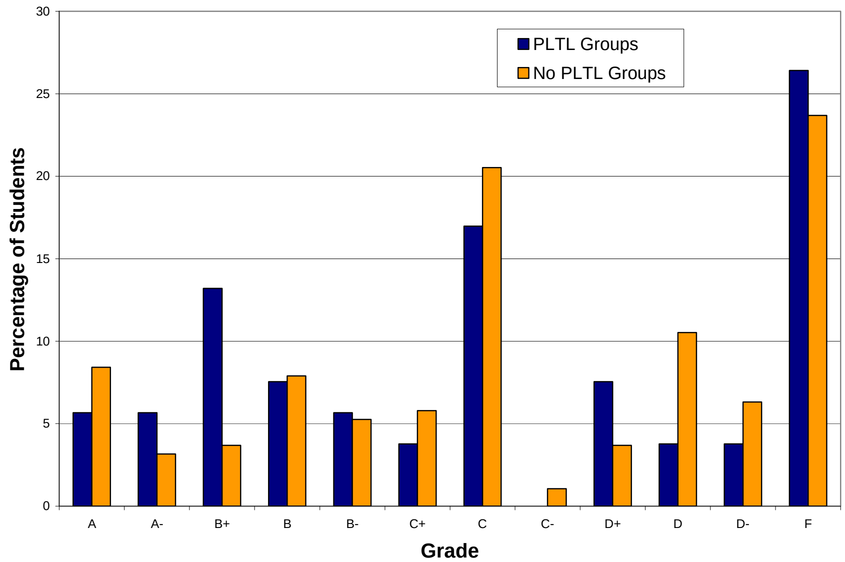

Figure 3: Percentage of each course grade earned by students who participated in the PLTL groups and those who did not participate in the PLTL groups for Math 116 in the Fall 2011 semester.

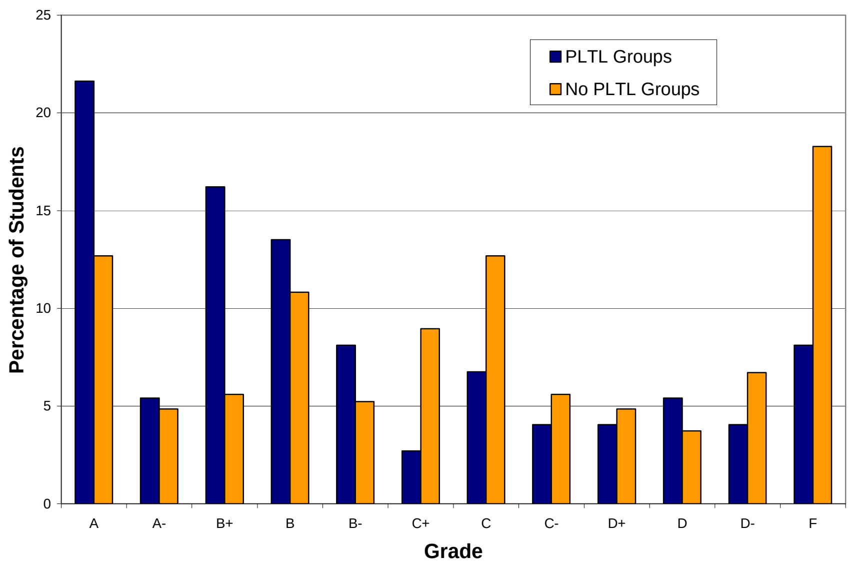

Figure 4: Percentage of each course grade earned by students who participated in the PLTL groups and those who did not participate in the PLTL groups for Math 231 in the Fall 2011 semester.

Table 1: Average course grades and statistical analysis for cohorts of students who participated in ("PLTL Groups") and did not participate in ("No PLTL Groups") 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.

		Math 231 Calculus I		**Math 116 College Algebra**	
		PLTL Groups	**No PLTL Groups**	**PLTL Groups**	**No PLTL Groups**
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	

As can be seen in Figures 1-4 and Table 1, 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.

Because the format of the 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 in that other factors, such as changes in burdens from outside courses or instructor changes, are then captured in the results. But the combined results, as shown in Table 1, also provide value by giving an overview of the impact of the program over multiple years. Figures 5 and 6 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 appear to improve student performance in Math 231, while having only a small impact in Math 116.

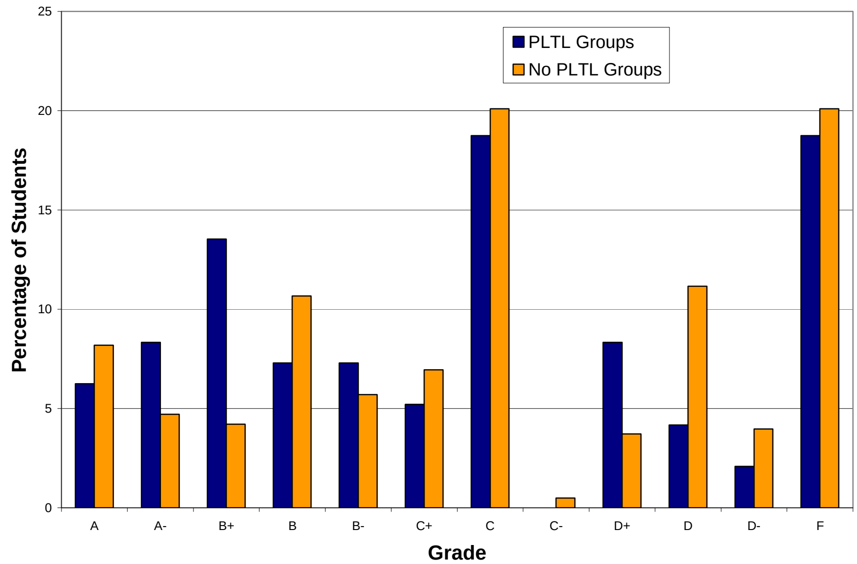

Figure 5: Percentage of each course grade earned by students who participated in the PLTL groups and those who did not participate in the PLTL groups for Math 116 in the combined Fall 2010 and Fall 2011 semesters.

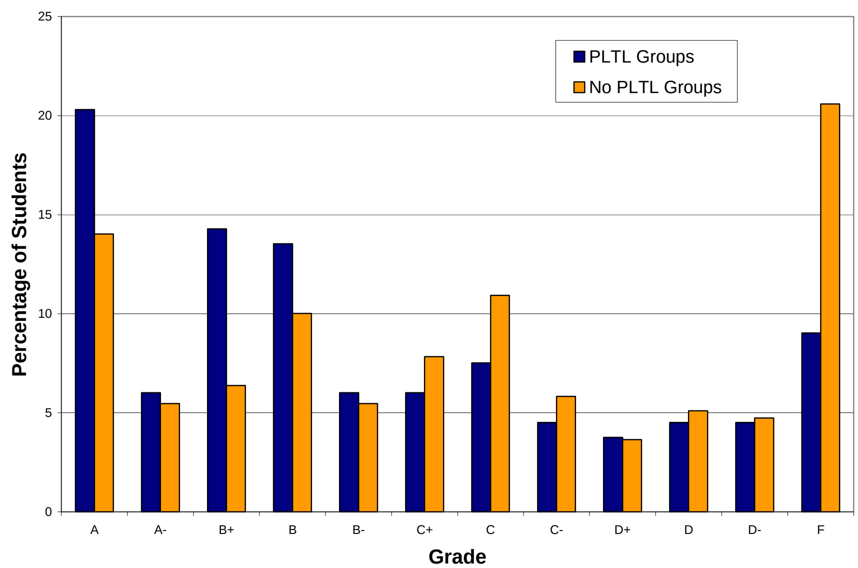

Figure 6: Percentage of each course grade earned by students who participated in the PLTL groups and those who did not participate in the PLTL groups for Math 231 in the combined Fall 2010 and Fall 2011 semesters.

Table 2: Average Course Grades and Statistical Analysis for Students who Participated in and Did Not Participate in PLTL Groups in the Spring 2011 and Spring 2012 Semesters.

Spring 2011	Math 232 Calculus II		Math 231 Calculus I	
	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	
Spring 2012	PLTL Groups	No PLTL Groups	PLTL Groups	No PLTL Groups
Average Course Grade	2.27	2.01	2.24	2.26
Std. Dev.	1.21	1.32	0.78	1.32
Students	30	261	18	249
ANOVA p-value	0.304		0.949	

As participation drops in the spring semesters, which in turn raises questions on the self-selection of students into the study groups, only a summary of the results for the Spring 2011 and Spring 2012 semesters for Math 231 and Math 232 (Calculus II) is provided in Table 2. Note, the populations of the students who participated in PLTL groups are greatly reduced for these semesters, but participants experienced dramatically higher average grades than non-participants in the Spring 2011 semester. The results from the Spring 2012 semester are inconclusive, with the small number of Math 231 PLTL group participants performing nearly identically to the non-participants, and with the Math 232 PLTL group participants performing noticeably, but statistically-insignificantly, better. It should be remembered that students who began in courses below Calculus I in the Fall 2011 semester were required to participate in the PLTL groups in the Spring 2012 semester, which may bring in a group of students who have weaker mathematical skills.

It is of interest to compare the results above to the differences seen between CEAS freshmen and the others in the courses for the baseline Fall 2007 data. Recall, CEAS freshmen earned slightly higher grades than others in Math 116 and Math 231 in that semester, but not to a high degree of statistical significance.

The data in Table 1 and in Figures 2, 4, and 6 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 CEAS students are considered, the performance of the PLTL group participants exceeds that of the non-participants by a large amount. Furthermore, the statistical significance of the

PLTL vs. non-PLTL participant comparison is very high, especially when compared to the lack of statistical significance in the baseline data.

Comparison of the grade distribution indicates a consistent trend of participants receiving grades in the A and B range at a higher frequency, while non-participants receive grades of C or below, and particularly grades of F, at a much higher rate. This does not mean that participating in a PLTL group changes grades of F into grades of A, but is more likely an indication that the grades are being 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 PLTL group 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 1 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 1/5 increase in a grade is very comparable to what was achieved by the Fall 2007 first-semester CEAS freshmen without PLTL groups. Impacts on the Math 117 students, not shown here, are even smaller. This suggests that the PLTL groups are having a minimal impact on the PreCalculus-level course performance of the freshmen engineering students. The course grade distributions shown in Figures 1, 3, and 5 confirm this. Unlike 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 2, the limited results for Math 232 PLTL groups indicate that they are successful for students participating in those groups. But 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 level of course grade improvement is on par with the other studies. Furthermore, as previously reported by Loui, et al.[10], 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 data for Math 116 in the Fall 2011 semester. In general the PLTL groups aid student performance, but the use of such groups is no guarantee of success for all students.

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 PreCalculus 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 were 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 and computer science freshmen have had the material covered in Math 116 previously in their secondary school educations; however, many 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 may 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.

Summary and 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 many students who can excel in their first college math classes without the use of PLTL groups.

Second, the PLTL groups appear to be much more beneficial to students in Calculus courses as opposed to PreCalculus courses. This does not mean that the PLTL groups are not helpful to students in PreCalculus 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 PreCalculus 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 math 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.

Acknowledgments

Partial support for this work was provided by the National Science Foundation's Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP) under Award No. 0757055. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. The authors would also like to thank Shuwen Tang, Cindy Walker, Todd Johnson, Tina Current, Sharon Kaempfer, and Jennie Klumpp (all at UWM) for their assistance with this project.

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