
AC 2012-2983: ANALYSIS OF THE IMPACT OF FORMAL PEER-LED STUDY GROUPS ON FIRST-YEAR STUDENT MATH PERFORMANCE

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

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. Reisel was a 2005 recipient of the UWM Distinguished Undergraduate Teaching Award, the 2000 UWM-College of Engineering and Applied Science Outstanding Teaching Award, and a 1998 recipient of the SAE Ralph R. Teetor Educational Award. Reisel is a member of ASEE, ASME, the Combustion Institute, and SAE. 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 and works to recruit and retain undergraduate minorities and women to UWM's College of Engineering and Applied Sciences. Jablonski is focusing her dissertation on sustainable oxidation of textile wastewater and is working to create small-scale wastewater treatment units for cottage textile industries. She trained at the National Environmental Engineering Research Institute (NEERI) in Nagpur, India where she worked on biodegradation of azo dye intermediates. Jablonski served as Co-chair of UWM's student chapter of Engineers Without Borders for two years since its inception in 2007 and continues to help design and implement water distribution projects in Guatemala. Jablonski was a 2008 recipient of the NSF Graduate Fellowship Honorable Mention, the 2008 Wisconsin Water Association Scholarship, and the 2007, 2008, 2009, 2010, and 2011 UWM Chancellor's Graduate Student Awards. Marissa is a member of ASEE and EWB. She received her B.S. degree in natural resources and Spanish from the University of Wisconsin, Stevens Point, in 2003, her M.S. degree in civil/environmental engineering from UWM in 2009 and will receive her Ph.D. in civil/environmental engineering from UWM in 2013.

Ethan V. Munson, University of Wisconsin, Milwaukee

Prof. Hossein Hosseini, University of Wisconsin, Milwaukee

Hossein Hosseini has received his Ph.D. in electrical and computer engineering from University of Iowa in 1982. He has been a faculty member with the Department of Electrical Engineering and Computer Science at the University of Wisconsin, Milwaukee (UWM) since 1983. Currently, he is professor and Chairman of the Computer Science Program. Hosseini's expertise is in the areas of computer networks, computer architecture, fault-tolerance, and distributed and parallel computing. He is the Founder and Co-director of the Computer Networks Laboratory at UWM. Hosseini has published more than 120 research papers in refereed journals and conference proceedings, one of his co-authored papers has won the Best Paper Award, and he has published two book chapters. He is the recipient of a patent in the field of computer networks. He has supervised nine Ph.D. and over 60 M.S. students and has received funding from NSF and industry. Hosseini is an internationally known figure; he has served on the editorial board of a journal and on the program committee of several international conferences. He regularly reviews research papers for various journals and conference proceedings and textbooks for book publishers. Hosseini has played a leading role in the development of Electrical Engineering and Computer Science programs including the development of the new B.S. degree program in computer engineering, the initiation of the Computer Science program accreditation by ABET, and the growth and expansion of curricula in computer architecture and computer networks, where he has developed several undergraduate and graduate courses. Hosseini has extensive administrative experience as well. In addition to serving as the Computer Science Chair, he has served in important committees such as College of Engineering and Applied Science Strategic Planning Committee, Division of Natural Sciences Executive Committee, and UWM Senate.

Analysis of the Impact of Formal Peer-led Study Groups on First-Year Student Math Performance

Abstract

Formal peer-led study 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 the study group were taking the same math course, although students did not necessarily come from the same course section. In the 2010-11 academic year, these groups were organized as a formal class, and students received a grade based upon their participation. This was done to increase participation rates over past years during which the study groups were offered in a less formal setting. Analysis of previous years' groups had indicated that greater participation in the study groups correlated with higher grades in the associated math courses.

Study groups featured 6-12 students, and were directed by an upper-level engineering or computer science student. The student peer mentor would pose math problems to the students in the class. These problems came from homework assigned in the math classes, additional non-assigned problems from the math books, and outside sources. The students then worked on the problems together, until a solution was found. The student mentor would provide guidance if the students were unable to solve a problem without assistance, but would not completely solve the problems for the students.

In the second year of the study, approximately 70% of the first-year students in engineering and computer science attended at least one session of the study groups, with nearly all students attending 9 or more of the weekly sessions. Grades of the students who participated in the study groups were generally 0.3-0.7 points (on a 4-point scale) higher than the average course grades of all students in the courses.

In this paper, the format of the study groups will be described in detail, and the analysis of the impact of the study groups on the student grades will be presented.

Introduction

There is great interest in the United States to increase the number of students graduating from college in the Science, Technology, Engineering, and Mathematics (STEM) disciplines.^{1,2} To accomplish this goal, two primary tasks need to be performed. First, more students need to be attracted to pursue college-level studies in the STEM fields. Second, once those students are enrolled in a STEM field, the colleges and universities must provide a nurturing environment designed to allow a wide range of students to succeed, while still 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 6-year graduation rate for Fall 2004

incoming freshmen for the college was 26.3%. Recognizing that this type of graduation rate is undesirably low in that it indicates that CEAS is not advancing many students to the ultimate goal of graduation in these STEM fields and that students who have shown interest in engineering and computer science have failed to achieve their goals, CEAS has sought to improve this through several activities. One of these activities is the creation of study groups for incoming freshman, with these groups being led by a higher-level undergraduate student who also serves as a peer mentor. The use of peer mentors and study groups is not a new concept, and has been shown to be successful elsewhere.³⁻⁷ As we have found that math courses tend to be one of the most difficult hurdles for incoming students to overcome, the study groups focus on the appropriate math courses.

Math is the foundational language for all engineering and computer science applications, and so a strong basic understanding of Algebra, Trigonometry, and Calculus for all students in CEAS is vital for success in subsequent courses. As part of an NSF-funded STEM Talent Expansion Program (STEP) grant, first-year students in engineering and computer science register for small study groups based upon their math course. The groups meet once a week for 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 project is now in its fourth year. During the first year (2008-09), the program was completely optional and voluntary for the students. Participation in the program was poor, so in 2009-10, students were assigned to specific study groups. While attendance improved, scheduling difficulties and a desire to increase attendance even further has led to the college formally entering study groups into their Fall 2010 and Spring 2011 class listings. Students are strongly encouraged to enroll in the study groups by their advisors. This has led to strong participation in the study groups in the Fall semesters, but 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 is 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 study 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. Students who participated in no study groups in a semester are considered in the category of “Did Not Participate”.

Format and Purpose of the Study 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 students in the college. Study 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. Learning problem solving skills in a group will inevitably raise the confidence levels of the students early in their college career. These skills will easily transfer to their independent work. The use of study groups is expected to increase retention and graduation and decrease such detrimental practices as cheating.

Mentor Preparation

The student peer mentors were hired and trained according to two *Peer-Led Team Learning* books: *A Guidebook*,⁶ and *A Handbook for Team Leaders*.⁷ 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 study groups, and success of having earned a 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 proves 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.^{6,7}

Mentors are required to prepare at least one hour per week for their groups. Mentors are assigned two or three study 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.

Study Group Logistics

As described elsewhere⁸, students arrive at study 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. In the case of a group with students from several different course sections studying different chapters of the book, the mentor may break the group into smaller more appropriate groups. 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 study 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 will typically be much less than the cost of hiring graduate TAs to lead these important but fairly low-level math study groups.

Study Group Evolution

Fall 2008 / Spring 2009

The study group initiative began in Fall 2008, when a single upper-level undergraduate engineering student was hired and made available for math coursework help at a central location in the college building. The time and location were advertised throughout the Engineering and Mathematical Sciences (EMS) building. Attendance was minimal and it was clear that the program needed more organization to benefit more CEAS freshmen.

Fall 2009 / Spring 2010

In Fall 2009 and Spring 2010, all registered CEAS freshmen were assigned to a study group based on their math course. The study groups had to be manually assigned and student schedules were filtered according to math level, time availability, and major. Assigned groups varied in size from 6 to 12 students per group; scheduling conflicts prevented the formation of uniformly-

sized study groups. Groups were created for the Intermediate Algebra course (Math 105), the combined College Algebra (Math 116) and Trigonometry (Math 117) courses, and the Calculus I course (Math 231).

While attendance was strongly encouraged, it was not required. It became apparent that many students assigned to groups did not recognize the benefit of the group. With the low interest shown during the Fall semester in mind, Spring 2010 study groups were assigned to have double the number of students as it was assumed that many students would not attend. Study groups were added for higher-level courses including Calculus II (Math 232) and Differential Equations and study groups for the Intermediate Algebra course was no longer offered. Study groups for the College Algebra, Trigonometry, and Calculus I courses continued to be offered.

Fall 2010/Spring 2011

To facilitate scheduling of the study groups, in Fall 2010 semester, a one-credit Introduction to Engineering course was introduced into the schedule of classes. Advisors recommended that all incoming CEAS freshmen register. Eighteen fifty-minute sections were made available on Mondays, Tuesdays, and Wednesdays at three different times: 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 were to register for the appropriate section based on their math course. Five new peer mentors were hired while two mentors remained from the year before to share their experiences and serve as role models for the new hires. Most incoming freshmen registered for the course and since it was a part of their schedule, the majority attended throughout the semester. Having the class as a part of their weekly schedule, coupled with introducing a grade for the course based upon participation, increased attendance. Nearly all students who participated in the study groups attended more than $\frac{2}{3}$ of the meetings.

However, participation again dropped for the Spring 2011 semester. Whereas 147 students participated in the Fall 2010 semester, only 40 participated in the Spring 2011 semester. While we are still analyzing the reasons for this drop, two likely reasons stand out. First, students often find their own friends and form their own study groups once they are at college. This will cause fewer students to participate in a non-required (though recommended) formal study group. Second, few students who participated in the study groups for Intermediate Algebra attended study groups in the Spring 2011 semester. CEAS students in Intermediate Algebra often find the material very easy, and tend to question the need for study groups more than students in the other math courses. These students may not appreciate the value of study groups based on their first semester experience.

Fall 2011 / Spring 2012

The same format for the Fall 2011 semester was retained. The most notable change for the Spring 2012 semester is that the CEAS advising office required that students who are in classes below Calculus I in the Fall 2011 semester register for study groups in the Spring 2012 semester. The students who take Calculus I in the Fall 2011 semester may still sign up for appropriate study groups, but it was not required. In addition, the college has worked with the Math

Department to save slots in the math courses so that students who are in the same section of a math class can be scheduled into the same study group.

Results and Discussion

Previous work⁸ analyzed the impact of the frequency of attending study groups with regards to course performance. That work focused on the Fall 2009 semester in particular, and also considered secondarily the Spring 2010 semester. Those semesters were used in the study because there was significant variation in the number of study groups that participants attended. In that study, it was seen that math course grades improved with the amount of attendance in the weekly study group sessions. Also of interest is that there was little difference in the degree of participation in the study groups in a particular course based upon an independent measure of student aptitude: math ACT scores. If anything, there was a small negative correlation suggesting that students of higher aptitude were less likely to attend the study groups.

Based upon those results, the study groups were formalized into a course with an associated grade based upon the amount of participation. Not only did this formalization increase the number of participants in the Fall 2010 and Spring 2011 semesters, but it also increased the degree of weekly attendance. As a result, nearly all students (90% in the Fall 2011 semester, 95% in the Spring 2011 semester) who participated in the study groups attended 9 or more of the weekly sessions, corresponding 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. Due to the large number of students who participated in the study groups in the Fall 2010 semester, and the high level of attendance, this analysis focuses on comparisons between the students who participated at all in the study groups and the remainder of the students in the course. This analysis will concentrate on Math 116, Math 117, and Math 231. Intermediate Algebra (Math 105) will be mentioned, but is not being analyzed to the same extent. Math 105 is the terminal math course for most students at UWM, and contains many students who have little interest in or use for math in their studies. As a result, when comparing the non-CEAS 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 study groups. It should be noted that approximately 15%-20% of the incoming freshmen in CEAS do place into Math 105 and so the study group experience is provided for them as well as other freshmen.

Math 116, 117, and 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 study group versus students who were not in the formal study groups, one is comparing students of similar backgrounds, needs, and aptitude for Math 116, 117, and 231. The students who did not participate in study groups for these courses fall into the following categories: (1) CEAS freshmen who chose not to participate in the study 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.

As mentioned, participation dropped for the Spring 2011 semester, such that there were only 4 students in the study groups for Math 116 and 117, 15 students in the study groups for Math 231, and 20 students in the study groups for Math 232. As a result, we will ignore the results for the College Algebra and Trigonometry courses.

Figure 1 presents the comparison between the Fall 2010 average course grade for students in Math 105, 116, 117, and 231 for two sets of students: one set is comprised of students who participated in the study groups, and the second set is the remainder of the students who received a grade in the course. The grades are on a standard 4.0-scale (A = 4.0, A- = 3.67, B+ = 3.33 ... D- = 0.67, F = 0). As can be seen in Fig. 1, the students in the study groups, on average, received higher grades than the students in the courses who did not participate in study groups. There is further elaboration of the data in Table 1, which also contains the standard deviations and sample sizes for Math 116, 117, and 231. In addition, the p-value from an ANOVA analysis of each data set is given. As can be seen, the p-value indicates a confidence level of 90% or more is met for all of the data sets, and the confidence level of Math 231 is well above 95%, with Math 117 falling just outside of this confidence level. This indicates that the benefits of the study groups on course grades are statistically significant to a high degree.

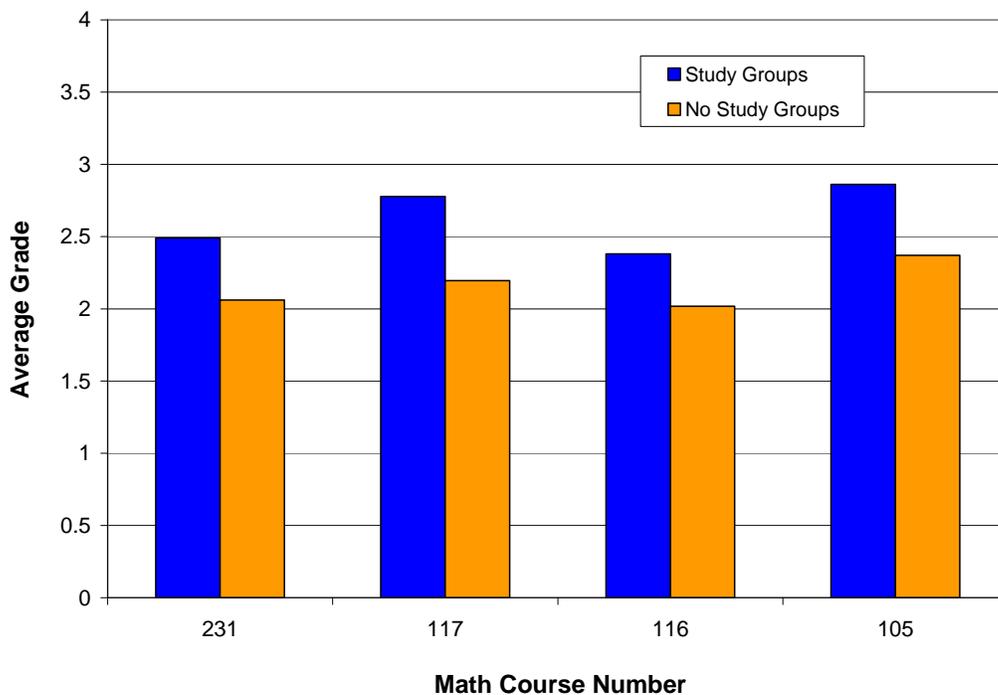


Figure 1: Comparison of Average Course Grades for Students in the Fall 2010 Semester Between Students Who Participated in Study Groups and Those Who Did Not Participate.

Table 1: Average Course Grades and Statistical Analysis for Cohorts of Students who Participated in and Did Not Participate in Study Groups in the Fall 2010 Semester.

	Math 231		Math 117	
	Study Groups	No Study Groups	Study Groups	No Study Groups
Average Course Grade	2.49	2.06	2.78	2.20
Std. Dev.	1.28	1.44	1.17	1.43
Students	59	281	24	228
ANOVA p-value	0.034		0.056	

	Math 116		Math 105	
	Average Course Grade	2.38	2.02	2.86
Std. Dev.	1.15	1.26		
Students	43	213	36	1,968
ANOVA p-value	0.084			

The results are further described in Figures 2-4, which contain for Math 116, 117, and 231 the percentage of students in the two groups who received a given course grade. As can be seen, in general the group of students who participated in the study groups tended to have a larger percentage of students who receive grades in the categories of C or above than the non-participants, while the students who did not participate tended to see higher percentages of students receive grades below C. While this feature does not hold true for each grade in each course, this is partially due to the few number of students in the study group cohort who received certain grades; i.e., the number of students in each finely parsed category becomes quite small and a variation of one or two can noticeably impact the percentages. However, what is important to note is that the trend of improved grades is present, reinforcing the result that the study groups do help contribute to higher course grades.

Figure 5 presents the average grades of the study group and non-study group cohorts in Math 231 and 232 in the Spring 2011 semester. As can be seen in Table 2, there are many fewer students in the two cohorts in comparison to the Fall 2010 semester, and as a result, the Math 231 results are not particularly statistically significant. However, the results of the Math 232 course are significant statistically, at over a 95% confidence level. Furthermore, when all of the results are combined from the two semesters, the students in the study groups are receiving, on average, a grade 1/3 to 2/3 of a letter grade higher than students who do not participate in study groups. This further lends credence to the usefulness of study groups for helping students understand the material.

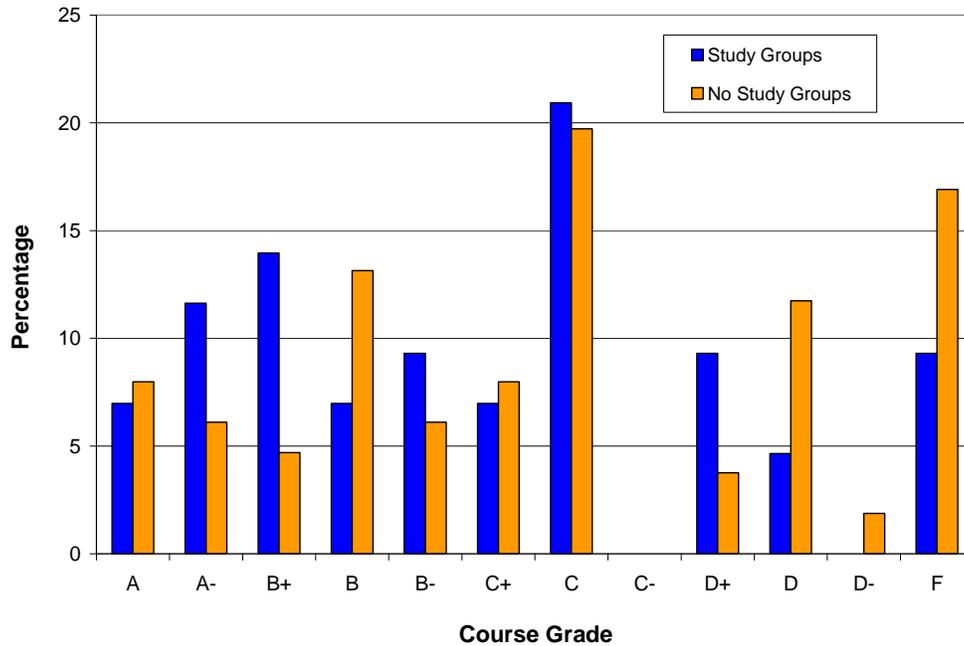


Figure 2: Percentages of Course Grades Earned by Students in Math 116 (College Algebra) in the Fall 2010 Semester, for Students Who Participated in Study Groups and Those Who Did Not Participate.

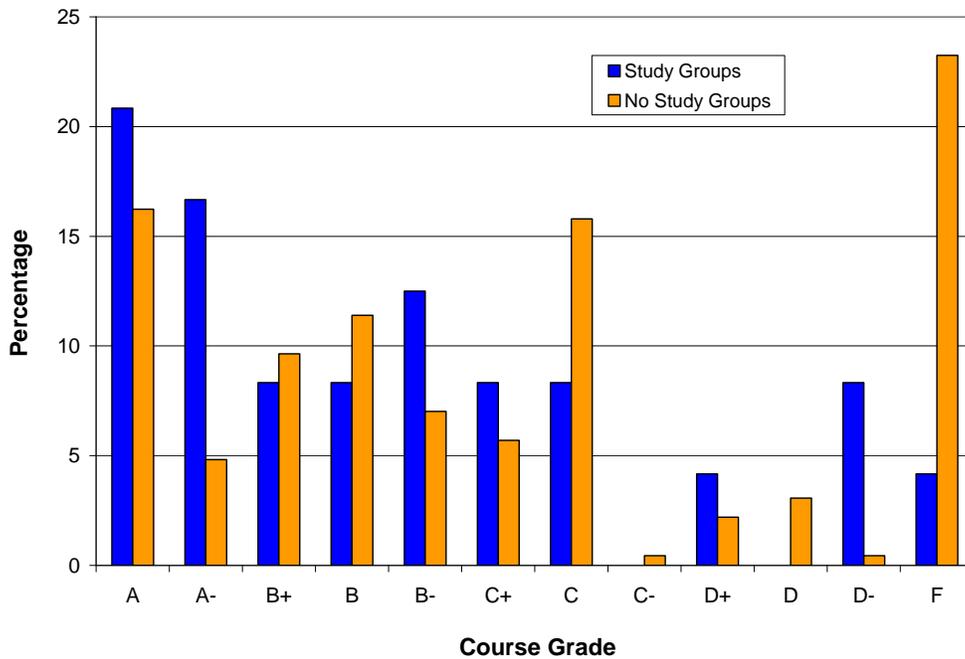


Figure 3: Percentages of Course Grades Earned by Students in Math 117 (Trigonometry) in the Fall 2010 Semester, for Students Who Participated in Study Groups and Those Who Did Not Participate.

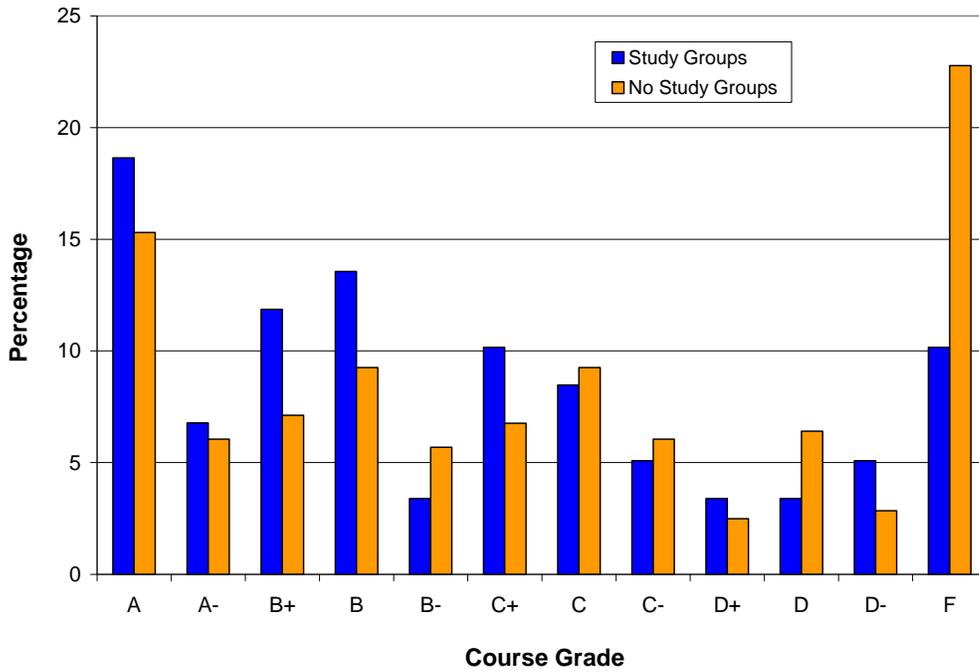


Figure 4: Percentages of Course Grades Earned by Students in Math 231 (Calculus I) in the Fall 2010 Semester, for Students Who Participated in Study Groups and Those Who Did Not Participate.

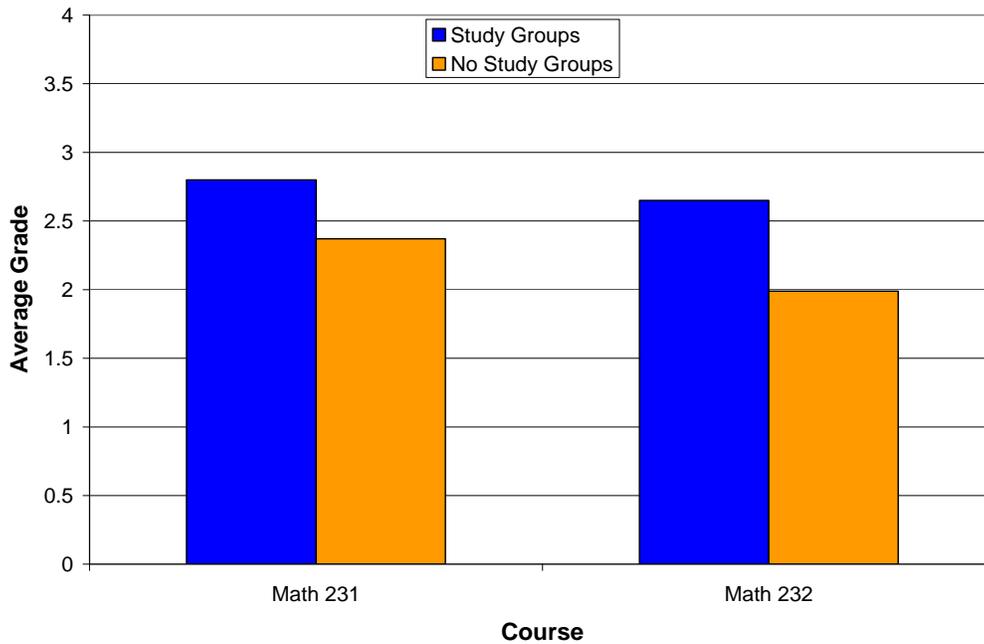


Figure 5: Comparison of Average Course Grades for Students in the Spring 2011 Semester Between Students Who Participated in Study Groups and Those Who Did Not Participate.

Table 2: Average Course Grades and Statistical Analysis for Cohorts of Students who Participated in and Did Not Participate in Study Groups in the Spring 2011 Semester.

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

One factor that is difficult to separate, particularly in the Spring 2011 semester is the quality of the student participating in the study groups, as well as their particular motivation to do well. In the Fall 2010 semester, the percentages of students in the study groups in each course were fairly substantial, and furthermore approximately 2/3 of the incoming freshmen in CEAS did participate in the study groups. Nonetheless, it is clear that the study groups do not hinder the students who participate in them, and there is strong evidence to support the conclusion that the study groups significantly benefit the students directly in their math grades. It remains to be seen if this will have a long-term effect on retention and graduation of the students, which is expected to be an additional benefit of the study groups.

Summary and Conclusions

Peer-led study groups have been developed for entering freshmen in CEAS at UWM. The study groups focus on the particular math course taken by the students in the group. Changes to the program format have increased the number of students who participate in the study groups to a significant degree. In the Fall 2010 semester, approximately 70% of incoming freshmen in CEAS participated in the groups, with nearly all of the students attending 64% or more of the weekly sessions. A comparison of the student performance for students who participated in the study groups versus those in the math courses who did not attend the groups shows that students who attend the groups consistently perform better in the math courses than students who do not attend these formal study groups. The courses of particular focus in this study are the College Algebra, Trigonometry, and Calculus I and II courses, as these are generally only taken by students at UWM who require higher-level math in their disciplines (primarily STEM disciplines). Each course under consideration for the Fall 2010 and Spring 2011 semesters showed a higher average course grade for study group participants, typically between 1/3 and 2/3 of a letter grade higher. It can be noted that most of the individual course analysis results were to a high degree of statistical significance, and that the trend of improved grades were consistent indicating the strength of the conclusion that the study groups improve student success in these math classes.

The peer-led study groups have advantages over TA-led sessions where TAs demonstrate how to solve problems. This does not mean that TA-led recitation sessions do not have value, but that these study groups offer an alternative that also offers potentially more benefits. In these study groups, the mentor is more closely connected to the age of the students, allowing a peer

mentoring relationship to more easily develop. In addition, it is the study group participants who work through the solutions, while the mentor helps the group through difficult parts if the group has reached an impasse. Finally, in general hiring undergraduate hourly workers is more cost effective than hiring TAs, which is an important consideration for many schools today. This is particularly significant when the use of the peer-led study groups has been demonstrated to be quite effective, as done here.

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