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Peer-Led Team Learning in Mathematics: An Effort to Address Diversity and Inclusion Through Learning and Leadership

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Janet Liou-Mark was a Professor in the Department of Mathematics at New York City College of Technology for 22 years. She organized the Peer Led Team Learning program at the college and served on the leadership team for many national grants. Her research focused on developing and evaluating programs that helped women and underrepresented minority and first-generation college students remain in school and successfully graduate with STEM degrees.

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Melanie Villatoro is an Associate Professor and Chair of the Department of Construction Management and Civil Engineering Technology at New York City College of Technology. Her outreach events target groups underrepresented in STEM and she seeks to increase diverse, qualified students entering STEM fields, particularly in engineering.

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Ariane Masuda is an Associate Professor in the Department of Mathematics at New York City College of Technology. She has extensive teaching experience in Brazil, Canada and the United States, and is dedicated to improving student performance. Her research interests lie in the area of Number Theory.

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Malika Ikramova is a current graduate student in the Department of Nutrition and Dietetics at New York University. She graduated summa cum laude from the New York City College of Technology (BTech '19). Her research interest lie in STEM education and through her relevant experiences in research, she aspires to become a pediatric clinical nutritionist in an oncology setting.

Farjana Shati

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Farjana Shati is an Adjunct Professor in the Department of Mathematics at New York City College of Technology, where she graduated with a degree in Mathematics Education with academic honors. She has been part of the Peer-Lead Team Learning Program since 2015 and aspires to work towards reducing world poverty and gender inequalities.

Julia Rivera

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Julia Rivera is an Adjunct Professor of Mathematics in the Department of Mathematics at New York City College of Technology and a continuing educator at Hostos Community College. She has been part of the Peer Led Team Learning Program for many years and enjoys helping students. Her mentor, Dr. Janet Liou-Mark, inspired her to become a better educator for women in the STEM field.

Victor Lee

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Victor Lee is an Adjunct Professor of Mathematics in the Department of Mathematics at New York City College of Technology. As a student, he was a Peer Leader and involved in the program for many years. His experience has led to his current placement as a graduate student in Mathematics Education at Brooklyn College.

The Peer-Led Team Learning (PLTL) model has shown to be an effective instructional method to support females, underrepresented minorities, and first-generation students in Science, Technology, Engineering, and Mathematics (STEM). The collaborative problem-solving setting, led by a peer leader, fosters learning that engages all the students. There are six critical components that are vital to the PLTL model: 1) The PLTL Workshop is integral to the course; 2) Faculty is actively involved; 3) Peer Leaders are well trained; 4) The PLTL Workshop modules are challenging; 5) PLTL workshops are allocated time and space; and 6) There is institutional support. City Tech has implemented the PLTL workshops in selected foundation mathematics courses over the past five years because of the dismal pass and withdrawal rates. Overall results have shown that females, underrepresented minorities, and first-generation college students who actively participated in the PLTL workshops have higher course grades and lower withdrawal rates. Students are also afforded the opportunity to participate in the PLTL Leadership program. Through the PLTL Leadership program, females, underrepresented minorities, and first-generation college students (107 peer leaders in total) who have successfully completing their STEM degrees, are either in the STEM workforce or pursuing advanced STEM degrees. The PLTL model supports students who are academically disadvantaged, and provides students with an opportunity to build their leadership skills and to create a pathway to graduate school.

Keywords: Peer-Led Team Learning, collaborative learning, leadership development, females, underrepresented minorities, and first-generation college students

Dedication: We would like to dedicate this manuscript in loving memory of Janet Liou-Mark, a role model and a champion for all who were fortunate enough to know her.

1. *Introduction*

The Peer-Led Team Learning (PLTL) model is an effective instructional method to support females, underrepresented minorities, and first-generation students in Science, Technology, Engineering, and Mathematics (STEM). Each week, eight to ten students are grouped together in a collaborative problem-solving setting to work on an assigned module supported by a peer leader. The peer leader is a former student who has taken the course previously and is quite familiar with the course content. There are six critical components that are vital to the PLTL model: 1) The integration of PLTL workshop into the course; 2) Faculty is actively involved and supportive; 3) Peer leaders are well trained in content and pedagogy skills; 4) The PLTL workshop modules are designed to be challenging; 5) PLTL workshops are allocated time and space; and 6) There is institutional support. The implementation of all the components provides a robust pathway toward undergraduates' academic success in their STEM courses using this model.

New York City College of Technology (City Tech) is a Hispanic-serving institution where 34 percent of the students self-identified themselves as Hispanic and 29 percent as African

Americans. Sixty-one percent report a household income less than $30,000, 62 percent are first in their family to attend college, and 80 percent of incoming freshmen receive need-based aid. City Tech has implemented the PLTL workshops in selected foundation mathematics courses over the past seven years because of the dismal ABC pass rates. Each semester, one to three sections of each mathematics course has a designated PLTL section with an extra problem-solving hour per week with a peer leader. These mathematics courses are identified as College Algebra and Trigonometry, Precalculus, Calculus I, and Calculus II. The average ABC pass rates for these courses have been approximately 50 percent. The overall withdrawal rate was approximately 15 percent which is consistent across all the foundational mathematics courses.

The six critical components were used as the basis in adopting the PLTL model in the mathematics courses. Each component will be described in detail. The first critical component is the PLTL workshop is integrated with the course. Undergraduates who registered for the PLTL sections have an extra hour attached to the course, similar to a zero-credit lab session. Peer leaders are assigned to a group of eight to ten students whom they work with until the end of the semester. The peer leaders are responsible for taking attendance and assigning a completion grade for the modules. A grade of 4 is given if the module is completely finished. A grade of 3 indicates a 75 percent competition and so forth. The goal of the PLTL workshop is for the students to develop meaningful discussions and to work collaboratively in solving the modules. The peer leaders are instrumental in helping the students find the solutions by providing hints, but the peer leaders are cautioned not to readily give out the answers which is different from tutoring. Moreover, the peer leaders do not grade each individual module, but they are cognizant that the group has the correct answer.

The second critical component is faculty is involved and supportive. Though the faculty is not directly present during the workshop, they are involved in making the workshops mandatory. They intentionally assign workshop participation as a percentage of the students' final grade and ensure that each weekly workshop aligns with the current lecture content. On the average, faculty would allocate 5-15 percent of the final grade for participation. Without the support of the faculty, students would start to wane from attending the workshop.

The third component is peer leaders are well trained in content and pedagogy skills. There are two elements of peer leader training, a two-hour content orientation and a one credit *Peer Leader Training in Mathematics* course. For content skill training, peer leaders are given the 12 modules before the semester begins and participate in a two-hour content orientation. Since they are not given an answer key, they must complete the modules before attending the content portion of the orientation that takes place a week before classes begin. Essentially by completing the modules ahead of time, they review the contents and anticipate the common problem areas their students may face. During the two-hour content orientation, their finalized answer keys are vetted and produced. For each module, meaningful discussions on the prior knowledge required, alternate solving techniques, and anticipated beartraps evolve during this time. For the pedagogy skill training, first-time peer leaders register for a one credit *Peer Leader Training in Mathematics* course offered by the mathematics department. The course content covers a brief overview of learning theories on behaviorism, cognitivism, and constructivism, facilitation strategies, and a session on stereotypes and diversity and inclusion. During the instruction portion of the orientation, peer leaders are coached on how to start the workshop with an ice-breaker and how to set the guidelines and expectations so that the future workshops become seamless. Content and pedagogy skills are covered in these two elements; however the practical application in the workshops is the best training the peer leaders can experience.

The fourth component is the PLTL workshop modules are designed to be challenging. Since the modules are intended to be solved collaboratively, the problem may have different ways to be solved. This intentional design invites thought-provoking discussions, fosters healthy debates, and at the same time, it increases the students' problem-solving abilities. Depending on the mathematics course, there may be as few as two problems or as many as six to solve during the one-hour period. Two example problems have been included below.

> PEER LED TEAM LEARNING MAT 1475 Sample Problem - Foundations
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> Sketch a graph of the distance travelled by a student over time from the first floor to the seventh floor of City Tech's elevator. Assume that the elevator stopped only on the 4th and 6th floors and spent approximately 3 minutes at each stop. Carefully state the assumptions you made. Does your graph represent a function?
>
> PEER LED TEAM LEARNING MAT1575 Sample Problem – Taylor Polynomials
>
> Compute p5(x) at the given a value for the following functions. (a) f(x) = sin(x) at a = 0 (b) f(x) = 1 1−x at a = 0 (Hint: Think about the geometric series from MAT1375.) (c) f(x) = ln (1 − x) at a = 0 (Hint: Compare the first derivative of this problem to the previous one.)

During the workshop the peer leaders encourage the students to work together to solve the problem and discuss their thought process as they work. Peer leaders are taught strategies for engaging different types of students in the workshop process. Their primary goal is to have the groups work together to develop a plan for solving the problem.

The fifth component states PLTL workshops are allocated time and space. As discussed, undergraduates who registered for the PLTL sections have an extra hour attached to the course, similar to a zero-credit lab session. This allows for the student to include the workshop in their weekly schedule and report to the same classroom each week. Having a dedicated time and space for students to work is an ideal setting for students to freely speak and ask questions amongst their peers, including the peer leader. Ideally, a healthy community is formed where the advanced learners are instrumental in fostering understanding among their peers.

The last component urges institutional support. The institutional buy-in would assist in providing professional development for faculty on how best to mentor the four peer leaders assigned to their course. As a comprehensive institution, there are no graduate students to assist the faculty. This model uses undergraduates so the expectations are slightly different from what is required from graduate students. This extra mentorship from the faculty is valuable especially for peer leaders who are underrepresented minorities and first in their families to go to college. In addition, the institution can assist in programming issues such as scheduling the additional one-hour workshops. More importantly, the institution will provide the stipends for the peer leaders. Typically, the peer leaders are given a $300 stipend for each course they peer led. This job may allow low-income and first-generation college students to stay on a commuter campus, so they can benefit from the academic support and extracurricular activities offered by the institution. Otherwise, these students will mostly seek off-campus jobs to fund their education and/or support their families.

Faculty support and proper allocation of time and space are two of the critical components that can contribute to reducing the impact of stereotype threat for female and minority students. Stereotype threat is an individual's expectation that negative stereotypes about his or her member group will adversely influence others' judgments of his or her performance and that a poor performance will reflect badly on the member group. Stereo type threat can contribute to lower performance of minorities in STEM courses (Deemer et al., 2014; Meador, 2018; Rivardo et al., 2008; Starr et al. 2019). These two components ensure that all students attend. If the faculty allowed flexibility in workshop attendance, those who can truly benefit from the extra help might not attend because of stereotype threat. Moreover, the dedicated space and the small group settings provide a more personable environment in which stereotype threats are less likely to affect academic performance (Rivardo et al., 2008).

Grades have been collected from Fall 2015 through Spring 2019 PLTL sections. Table 1 compares the PLTL sections using the Spring 2019 institutional data as a comparison. Although the pass rates have been relatively the same, the failure and withdrawal rates of PLTL sections are smaller. Students are able to pass their mathematics classes.

Table 1: Grades of PLTL Mathematics Sections and 2019 Institutional Data

2.	Intermediate Algebra & Trigonometry		Precalculus		Calculus I		Calculus II	
	PLTL Sections	Spring 2019 Institutional Data	PLTL Sections	Spring 2019 Institutional Data	PLTL Sections	Spring 2019 Institutional Data	PLTL Sections	Spring 2019 Institutional Data
	(n=642)	(n=1592)	(n=662)	(n=926)	(n=349)	(n=622)	(n=778)	(n=385)
Pass rates: ABC	54.0%	51.0%	57.3%	56.0%	57.3%	64.0%	53.2%	56.0%
Pass rates: ABCD	67.4%	69.0%	71.9%	72.0%	67.6%	75.0%	67.7%	71.0%
W/WU/WN	12.1%	21.0%	9.7%	14.0%	18.3%	16.0%	12.9%	21.0%
F	20.4%	31.0%	18.3%	28.0%	13.8%	26.0%	19.4%	29.0%
INC	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%

A small study was conducted using Fall 2015-Spring 2018 PLTL sections. The course final grades (out of 4.0) and the uniform departmental final grades (out of 100) were recorded for all the PLTL participants. Participants who were missing their gender, first generation status, and ethnicity were excluded in the study. First generation college students are defined by being the first in their families to attend college. An a analysis for African-American and Hispanic/Latino students determined no significant difference between the two populations therefore the data is presented for minorities, which includes African-Americans and Hispanics/Latinos as one subgroup. Non-minorities include Caucasians and Asian-Americans. Results have showed that females do overall statistically significantly better than their male counterparts especially in the lower level mathematics. First-generation college students tend to do better than non first-generation college students. However, the results were not statistically significant. Non-minority students did statistically significantly better than the minority students. These positive results were attributed to the collaborations and community formed with their peers, being able to freely discuss solutions, and having a dedicated safe space to work out problem sets. Table 2 summarizes the results.

Workshop participants respond to student satisfaction survey before and after their workshop experience. Survey questions ask about their satisfaction with the efficacy of the workshops including group dynamics, materials used, and time allotted for each activity. A Likert scale with one indicating "strongly disagree," with three as "neutral," and with five as "strongly agree" was used. Minorities responded that the PLTL sessions were very helpful in understanding the materials, in providing a comfortable space for asking questions, and in succeeding in the course. The PLTL program can be categorized as a positive contributor to minority retention in STEM courses. Determining the factors that positively contribute to minority STEM major recruitment and retention, may allow for the elimination of stereotype threats that hinder academic success for minority students in the STEM fields (Meador, 2018).

Table 2: Means (Standard Deviations) and Z-test Results by Mathematics Courses

Mean **(SD)** Sample size	**Females**	**Males**	**Z-test**	**First Generation**	**Non-First Generation**	**Z-test**	**Minority**	**Non-Minority**	**Z-test**
College Algebra & Trigonometry Course Final Grades	2.21 (1.29) *(n=132)*	1.95 (1.36) *(n=249)*	z=0.03, p=0.06	2.25 (1.26) *(n=109)*	1.97 (1.37) *(n=225)*	z=1.82, p=0.07	1.83 (1.33) *(n=223)*	2.35 (1.32) *(n=146)*	z= -3.72, p<0.001*
College Algebra & Trigonometry Department Final Grades	67.55 (22.11) *(n=132)*	62.51 (23.98) *(n=249)*	z=2.06, p<0.05*	67.44 (22.99) *(n=109)*	63.56 (23.90) *(n=225)*	z=1.43, p=0.15	60.81 (23.94) *(n=223)*	69.44 (21.64) *(n=146)*	z= -3.59, p<0.001*
Precalculus Course Final Grades	2.652 (0.993) *(n=109)*	2.01 (1.27 *(n=239)*	z=1.96, p<0.001*	2.35 (1.2) *(n=124)*	2.14 (1.21) *(n=224)*	z=1.96, p=0.12	1.98 (1.2) *(n=214)*	2.59 (1.16) *(n=134)*	z=1.96, p<0.001*
Precalculus Department Final Grades	72.54 (18) *(n=109)*	65.2 (21.05) *(n=239)*	z=1.96, p<0.001*	68.9 (21) *(n=124)*	66.6 (19.84) *(n=224)*	z=1.96, p=0.33	63.86 (20) *(n=214)*	73.24 (18.9) *(n=134)*	z=1.96, p<0.001*

Calculus I Course Final Grades	2.37 (1.38) *(n=103)*	2.06 (1.20) *(n=238)*	z=1.96, p<0.05*	2.24 (1.29) *(n=116)*	2.15 (1.24) *(n=203)*	z=0.61, p=0.54	2.06 (1.22) *(n=163)*	2.39 (1.24) *(n=131)*	z= -2.24, p<0.05*
Calculus I Department Final Grades	65.44 (22.06) *(n=103)*	63.35 (21.11) *(n=238)*	Z=0.81, p=0.42	63.16 (22.10) *(n=116)*	64.68 (20.84) *(n=203)*	z= -0.60, p=0.55	61.82 (21.42) *(n=163)*	68.40 (20.10) *(n=131)*	z= -2.71, p<0.01*
Calculus II Course Final Grades	2.36 (1.24) *(n=33)*	2.27 (1.22) *(n=97)*	z = -0.36, p=0.72	2.36 (1.27) *(n=40)*	2.24 (1.25) *(n=83)*	z=0.46, p = 0.65	2.01 (1.24) *(n=61)*	2.14 (1.17) *(n=47)*	z= -2.27, p<0.05*
Calculus II Department Final Grades	70.15 (19.27) *(n=33)*	70.28 (15.71) *(n=97)*	z= -0.03, p=0.97	71.70 (15.68) *(n=40)*	68.47 (18.33) *(n=83)*	z=1.01, p=0.31	2.01 (1.24) *(n=61)*	2.14 (1.17) *(n=47)*	z= -2.27, p<0.05*

The benefits of PLTL instructional model is two-fold. Firstly, it is designed to provide additional assistance for the students enrolled in fundamental mathematics courses, and secondly, the peer leaders are seamlessly enlisted into the PLTL Leadership Program. Through this leadership program, a community of practice consisting of new and experienced peer leaders is constantly forming and strengthening. This support network is where mathematical and general knowledge are shared, mathematical and leadership confidence are continuously building, the pursuit of STEM advanced degrees is encouraged and supported, and informal mentoring is practiced.

Peer leaders are trained in content and pedagogy skills. These pedagogy skills can be transferred to other subjects and disciplines. At City Tech, the PLTL program has expanded beyond math courses and has been implemented in science and engineering courses. Peer Leaders have had the opportunity to lead workshops across disciplines. The benefits of Leaders applying their skills to multiple disciplines, include an increase in confidence, reinforcement of their existing content knowledge, and expansion of their influence circle for serving as a role model.

> *"Being a Peer Leader in different subjects has helped me grow not only as a facilitator but also as a leader. Always be prepared. The PLTL workshop format is the same for all these subjects. Although the concepts are different, the math does not change. Another important aspect to be a good facilitator is the willingness to do it. In my case, I wanted to be good at it, I wanted to share my ideas and how I get around the problems. It is a beautiful thing to see students understand a new concept."*
>
> *-Construction Engineering Technology student and Peer Leader*

The PLTL program equips and empowers Peer Leaders with the leadership and confidence to work with students and faculty across the college.

Moreover, the students not only benefit in participating in the PLTL workshops, but they are also afforded the opportunity to participate in the PLTL Leadership program which formally trains students to become peer leaders. Studies have showed that role models who look like them enhance their perceptions and confidence in succeeding their STEM majors (Hutton, 2019; Shin et al., 2016; Weber, 2011). Through the PLTL Leadership program, females, underrepresented minorities, and first-generation college students (107 peer leaders in total) who have successfully completing their STEM degrees, are either in the STEM workforce or pursuing advanced STEM degrees. Approximately 35% of the graduates have completed or are continuing with their masters or doctoral degrees in STEM. To address the issues of diversity, equity, and inclusion in the mathematical sciences, instructional models such as PLTL may support this effort. The PLTL model supports students who are academically disadvantaged, and it also provides students with an opportunity to build their leadership skills and to create a pathway to graduate school, because there are not many role models who look like them in the mathematical sciences.

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